ToMCAT Offline Viz

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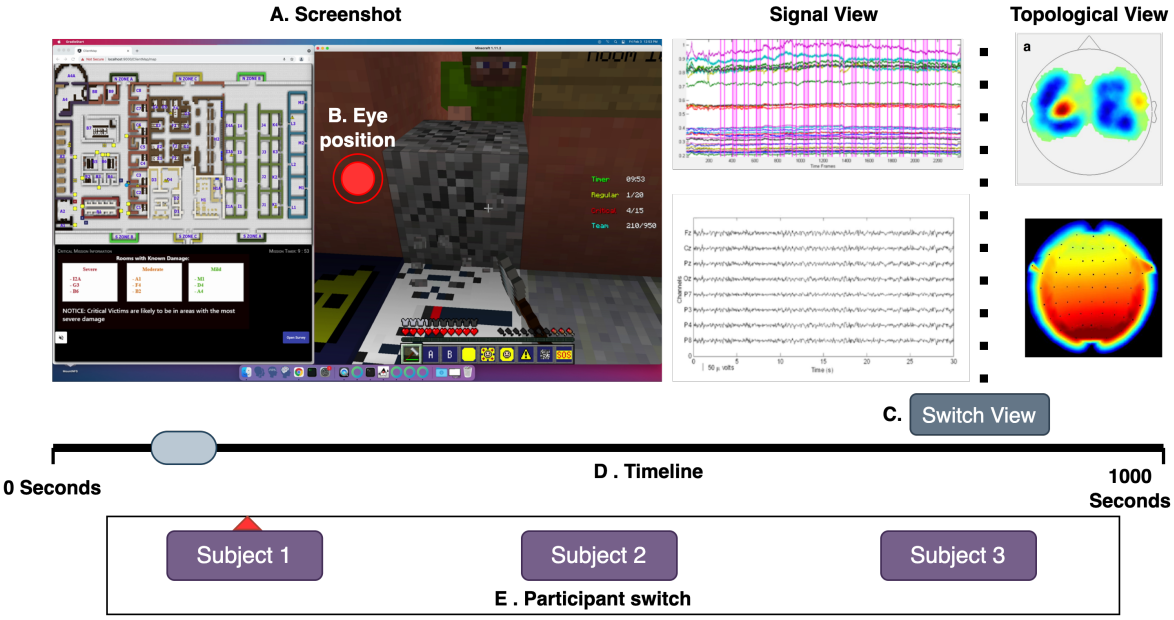

Fig. 1: Tomcat Offline Viz tool

Abstract— ToMCAT (*Theory of Mind-based Cognitive Architecture for Teams*) offline viz tool is a collaborative project to develop an all-in-one multimodal (fNIRS, Eye tracker, EEG) visualization tool. To achieve this goal, the project accepts experimental data in the form of CSV files and screenshots (PNG) and visualizes this data to the users in a way that is easy to understand and analyze. The tool utilizes multiple modes of data, including functional near-infrared spectroscopy (fNIRS), eye tracking, and electroencephalography (EEG), to provide a complete picture of the cognitive and perceptual processes, such as attention, working memory, and emotion. By using this tool, researchers can gain valuable insights into how team members interact with each other through varying tasks and environments. The tool presents the data in a visually intuitive manner, by superimposing screenshots with eye-tracking data on the left and fNIRS/EEG data on the right. The ToMCAT Offline Viz tool is a valuable resource for social and computer scientists who are working on the ToMCAT project. It helps the users to read and analyze multimodal data in a way that is both efficient and informative, and to use this data to design an AI agent that can facilitate team coordination and global team optimization.

1 Introduction

The Theory of Mind-based Cognitive Architecture for Teams (ToMCAT) [5] project proposes to provide integration of all of the critical capabilities for developing AI agents that work in teams. The abilities include accurately inferring the internal states of other agents, collaborating with them to solve problems, and communicating in a socially aware manner. The project aims on designing an AI agent that focuses on several key abilities essential for effective collaboration and combines them into a single cohesive framework.

However, to achieve this goal, the project faces a significant challenge in understanding the complex cognitive and neural mechanisms underlying teamwork. To address this challenge, we propose the development of an innovative visualization tool, named "*ToMCAT Offline Viz*," which combines multiple modalities to assist researchers in the analysis of experimental data. The problem we are trying to solve is the lack of comprehensive and user-friendly visualization tools for researchers who want to study cognitive and neural mechanisms. This problem is important because social and computer scientists working on ToMCAT project can gain a better understanding of how individuals interact within teams, and how cognitive and neural mechanisms underlie effective coordination with visualization.

The tool will allow researchers to superimpose eye-tracking data onto screenshots, providing insights into where team members direct their visual attention, while also displaying functional Near-Infrared Spectroscopy (fNIRS) [4] and Electroencephalography (EEG) [3] data on the right-hand side of the screen, providing information on neural activity. To further enhance visualization and facilitate analysis of variations, a slider can be utilized to compare the continuous changes.

The aims of this research are:

- Develop an innovative and user-friendly visualization tool to analyze multiple modalities including eye-tracking, fNIRS, and EEG, to provide a comprehensive understanding of the cognitive and neural mechanisms underlying teamwork.
- Enabling researchers to gain insights by providing a compact approach to visualizing complex data, which includes where team

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members direct their visual attention and how effective their coordination is by showing the change of trend in physiological data.

- Aiding the development of effective AI agents for team coordination and global team optimization.

2 Background

The ToMCAT [5] project is comprised of a set of local agents (one for each human teammate) equipped with cameras and microphones to capture facial expressions and speech, as well as virtual sensors that record the local environment, the actions performed by human teammates, and chat exchanges between them.

The multimodal data includes:

a. Functional Near-Infrared Spectroscopy (fNIRS) is a technology that can identify which parts of the brain are being used during an activity. When a specific part of the brain is activated, the blood flow to that region increases. By detecting changes in the concentration of the blood in the brain, fNIRS can determine which parts of the brain are most active [4].

b. Electroencephalography (EEG) is a technique used to record the spontaneous electrical activity of the brain in the form of an electrogram [3].

c. Eye tracking involves the detection of the human pupil and the subsequent recording of eye movements and fixations while viewing images or any other content on screen [2].

2.1 Related Work

Visualization Related: **Pupil Player** is a crucial tool for researchers who use Pupil Capture to collect eye-tracking data. It provides a user-friendly interface for visualizing recorded data and analyzing it. Additionally, Pupil Player enables researchers to export their data into various formats, making it easier to analyze and share with other researchers. Visualization plugins include Vis Circle, Vis Cross, Vis Polyline, Vis Light Points, and Vis Eye Video Overlay. Analysis Plugins include Surface Tracker, Fixation Detector, Blink Detector, Head Pose Tracking, IMU Timeline [2].

The **nirsLAB package** is an adaptable software analysis environment designed to facilitate the examination of time-varying near-infrared measurements of tissue. It is particularly well-suited for analyzing data acquired using NIRx systems [6].

BrainVision Analyzer is used by Scientists to process a variety of neurophysiological data. For ToMCAT project, EEG data is being collected. Analyzer is easy to use and offers a variety of powerful features for processing and visualizing EEG data [1].

Fig. 2: ToMCAT Experimental Paradigm

Domain Specific Related: Referring to Fig. 2, each experiment usually 3 participants and they follow a fixed instructed paradigm containing eight different tasks done in sequence:

A. Rest state: The participants are requested to sit back and relax for 300 seconds.

B. Finger-tapping individual task: The participants tap the spacebar on the keyboard for 10 seconds.

C. Finger-tapping team task: The participants tap the spacebar on the keyboard for 50 seconds in sync with each other based on visual feedback.

D. Affective individual task: The participants see an image for a few seconds on screen and they rate it based on its arousal and valence score. This is done for a total of 15 images. This lasts for roughly 3 minutes.

E. Affective individual task: The participants see an image for a few seconds on screen and they rate it based on its arousal and valence score after discussing it with each other. This is done for a total of 15 images. This lasts for roughly 11 minutes.

F. Minecraft training mission: This is for a mission tailored to train participants based on their role as medic, transporter, and mechanic.

G. Minecraft Saturn A mission & H. Minecraft saturn B mission : These are two missions with different environments where participants with their roles as medic, transporter, and mechanic have to team up and collaborate to rescue critical victims placed in their environments.

3 Research Plan

Referencing Section 1, our goal is to develop an innovative visualization tool to read and analyze complex data, including eye-tracking, fNIRS, and EEG, to provide a comprehensive understanding of teamwork. By developing ToMCAT offline viz, we plan to provide an innovative and user-friendly approach thereby supporting the research team in analyzing experimental data.

Fig. 1 gives a brief overview of ToMCAT offline viz tool.

The tool would have the following sections:

- **(Label A & B)** Fixation of Eye position superimposed over the screenshots with the diameter of circle changing based on pupil dilation on the screen.
- **(Label C)** A button that would switch between topological and signal view for EEG and fNIRS data.
- **(Label D)** A slider to scrub through the experiment timeline.
- **(Label E)** Three buttons to switch between participants.

3.1 Data

We have retrieved the data from LangLab arranged by Caleb who is an active member of the lab working under the supervision of Dr. Adarsh Pyarelal and Dr. Kobus Barnard. We have taken permission from the lab regarding the usage of the data.

The data consists:

Data type	Data Description
Experimental Images	PNG image format (Resolution: 1280X720, File size $\sim$ 600 kB) Sampled at 10 Hz
fNIRS	CSV Format (File size approx 53 MB) Sampled at 10.2 Hz
Eye Tracker	CSV Format (File size approx 140 MB) Sampled at 200 Hz
EEG	CSV Format (File size approx 1.2 GB) Sampled at 500 Hz

3.2 Evaluation

LangLab has been collecting multimodal data for the ToMCAT project since the Fall of 2021, providing us with an abundance of data to work with. Our only constraint will be ensuring that the ToMCAT offline visualization tool functions smoothly with limited system resources.

To evaluate the project, we will be soliciting feedback from computer and social scientists regarding their experience using the tool. Specifically, we will be asking for their opinions on the tool's user-friendliness and overall effectiveness.

3.3 Technology

Programming language: Python 3.9

Libraries: PyQt, CV2, Pandas, Matplotlib, MNE-Python PyQt5 is a cross-platform GUI toolkit that will help us to develop an interactive desktop application. CV2 is an OpenCV package for Python that serves for image loading, image compression, etc. Pandas will be used to load data from CSV files allowing the working of "relational" or "labeled" data.

Matplotlib would allow us to create static, animated, and interactive visualizations. MNE-Python might be used for a topological view of the brain for EEG and fNIRS signals.

3.4 Timeline

Milestone 1: Develop a skeleton viz tool where there we should be able to scrub through the timeline and visualize screenshots like video play-black.

Milestone 2: Superimpose eye positions over the screenshots such that we can visualize changes in gaze location and screenshots when we scrub through the timeline.

Milestone 3: Add a section to the right that shows a signal view for fNIRS signals.

Milestone 4: Add a section to the right that shows the topological view for fNIRS signals along with a button to toggle between the topological view and signal view.

Milestone 5: Start working on the project report. If time permits add a topological view for EEG signals along with a button to toggle between the topological view and signal view.

Milestone 6: Complete the project report and work on the project presentation.

Table 1: Project Milestones

Milestone	Description
March 17	Skeleton of the viz tool (Basic structure design)
March 24	Eye positioning for gaze fixation
March 29	Progress Update with the addition of fNIRS signals
April 7	Topological view implementation to switch from signal view
April 21	Project Initial Report of viz tool with defined subsections
May 3	Final Report Completion

4 Impacts

All the modalities have their own proprietary visualization software and using various proprietary software makes it difficult to analyze and visualize the multi-modal data. Therefore, getting a single software would help them accomplish this task. Details about the proprietary software of each modality is mentioned in Section 2.1.

The ToMCAT offline viz tool would allow social and computer scientists working on ToMCAT project to visualize multi-model data all in one place, allowing them to find correlations between various modals of data.

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