Performance Assessment of a Chemical Plant Operator using Physiological Signals

Objective:
To estimate the Cognitive Model of Chemical plant operators using eye-tracking data.

Apparatus:
Computer system (running Windows 11)
Eye-tracker: Smart eye Aurora (120 Hz)

Theory:
Accidents continue to occur in industries despite advancement in safety systems. Detailed analysis indicates, human error as a key contributor to these incidents; human error is the root cause of over 70% of accidents in chemical plants. The high cognitive workload experienced by operators during emergency situations is considered a key performance determinant, that can result in human error. Thus, it becomes imperative to devise a methodology that can measure cognitive workload.
Physiological measures like gaze tracking, heart rate variability, skin conductivity, electroencephalogram, etc. have a great potential to provide insights into human cognition, as the person's internal state involuntarily manifests in these measures. In this experiment we use eye-tracking to estimate cognitive workload of operators.
Eye-tracking: Eye-tracking is a technique used by researchers to record the person's eye movement and point of gaze. A typical eye movement consists of fixation and saccade. Fixation is the period during which the eye remains still and is necessary to process the information presented on the Human-Machine Interface (HMI). The movement of the eye from one fixation toanother is called a saccade. Researchers frequently use the term Areas of Interest (AOIs), which refers to the many locations on the HMI from which information is gathered. The duration of a fixation reflects one’s mental ability and density of information in a particular AOI. Dwell time isthe summation of all fixation duration within an AOI and represents attention given to a particular AOI. Likewise, measures such as saccadic duration and saccadic amplitude are based on saccades, which gives insights into the complexity of a visual search task.


a) Remote Eye-tracking setup

Methods
1. Connect eye-tracker to the system
2. Perform Calibration
3. Start recording of both gaze data and scenes in screen
4. Start the simulation of the experimental testbed.
5. Stop recording after completing the task

Experimental Testbed

The experimental test consists of a simulated ethanol process to which the participant interacts via the Human Machine Interface (HMI). The operator's job is to monitor the process for any disturbances and take corrective action(s) in the form of control valve manipulations (using the sliders in the HMI) as necessary.

Data analysis

The data collected from the sensor includes many physiological parameters like pupil diameter, eye blink frequency, gaze coordinates, fixation duration, gaze velocity etc. Gaze coordinates and fixation duration are considered as major signals and are used to estimate cognitive model of the operator about the ethanol process.

The schematic of the EEG signal processing is shown below.

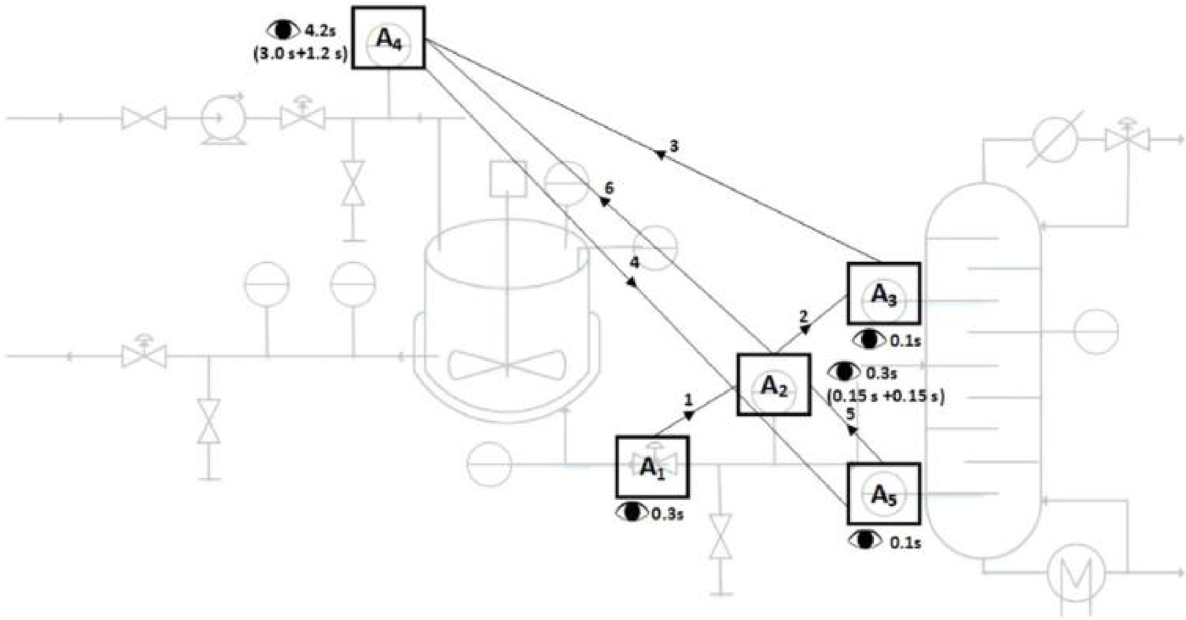

Fig. Schematic representation of the EEG signal processing

Eye-tracking analytics: Map the gaze coordinates data collected with the predefined vertices of various elements in HMI to find the area which the participant was currently looking at. Based on the above analysis plot the gaze-time plot and fixation-time plot. Visualize the attention distribution of participants using a Heat map. Operator attention needs to be distributed only on a few regions important for task completion.

Results:

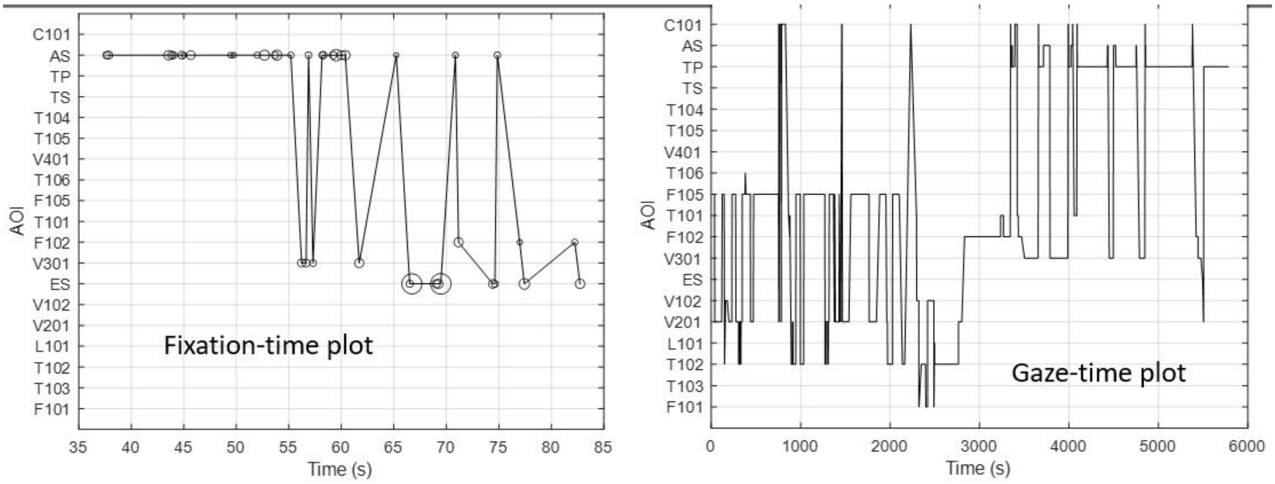

Fig. Fixation-time plot and gaze-time plot

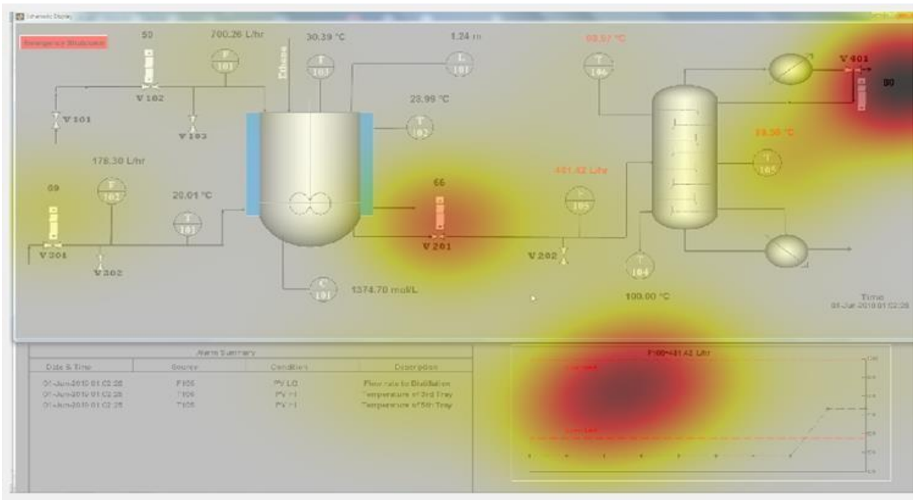

Fig. Heat map obtained from eye-tracking data

The heat map indicates that the participant has attention to only three areas on the HMI.

Conclusion

For the performed experiment there are specific areas alone in the HMI screen which alone are relevant and therefore the operator is typically expected to look at those elements alone. Moreover, the sequence of (Area of interest) AOI and the fixation duration spent by the operators conveys the information about the cognitive model of the operator about the process.