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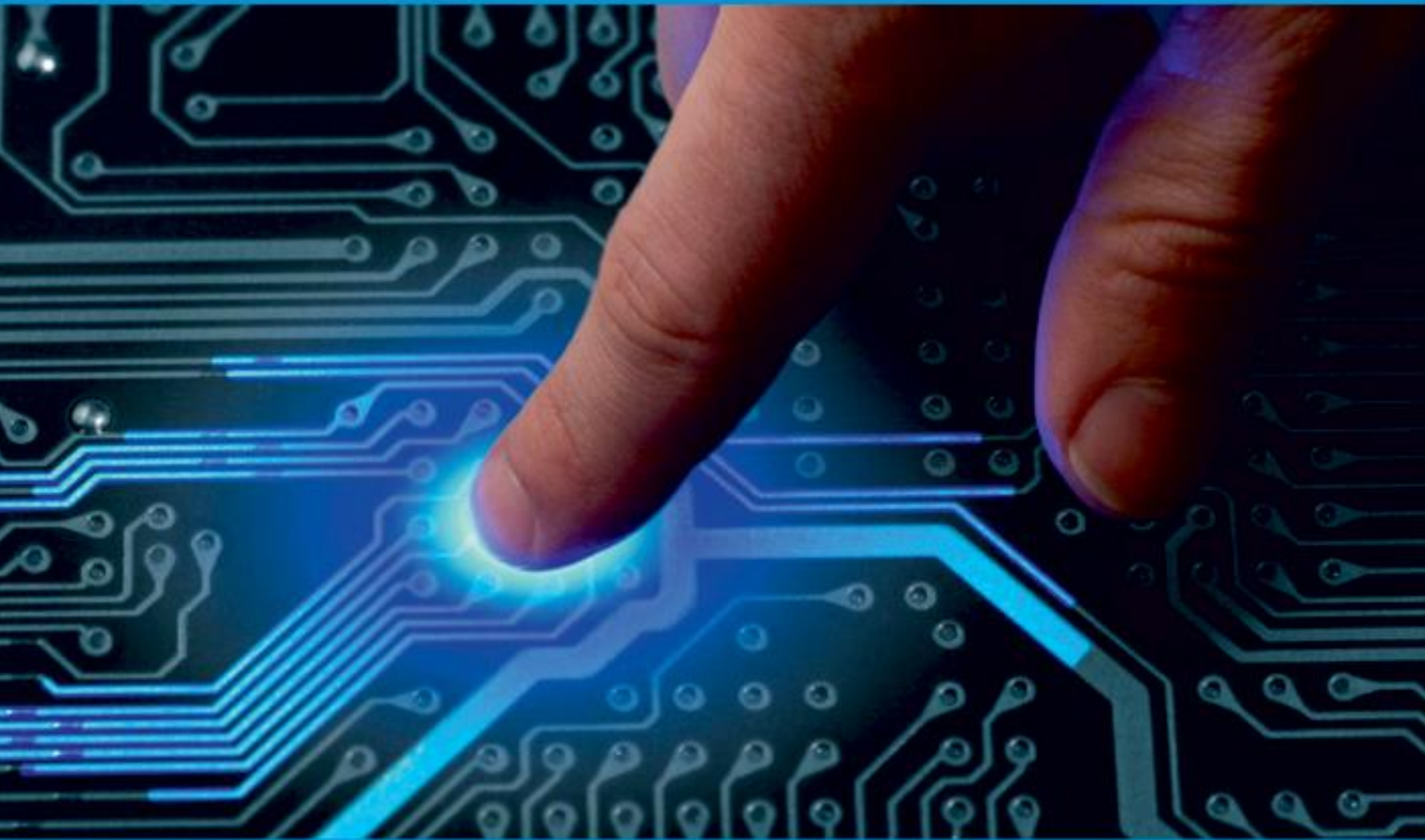

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# Eye Tracking in Automobile and Aviation Studies: Implications for Eye-Tracking in Marine Operations

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**ABSTRACT:** In the last decade researchers have increasingly considered eye tracking of the operators of cars and airplanes as a means to address human error and evaluate operational effectiveness. This article presents a systematic survey of recently published papers about this approach in service to the question as to whether eye tracking can be used to address operational safety in marine operations. The surveyed papers are selected systematically and were categorized according to several defined characteristics. Eye tracking depends on defining operators' areas of interest (AOIs) and measuring operators focus on them over time.We identified the method of defining AOIs as a key distinction between studies; the papers fell into four categories, depending on whether researchers relied on an expert, based it on the stimulus itself, or used an attention map or a clustering algorithm to define the AOIs they used. The article also summarizes and analyzes the design and procedure of the eye-tracking experiments in the papers. Based on the features of marine operation, instruction on AOI definition in different scenarios is extracted; guidelines on experimental design and procedure selection are provided. In the article's conclusion we apply the results to a case study of a heavy-lifting operation to demonstrate the effectiveness of eye-tracking in marine operations

**KEYWORDS**: Area of interest (AOI) definition method, automobile and aviation, eye tracking, knowledge transfer, marine operation

## I. INTRODUCTION

EYE tracking is a sensor technology that captures human eye behaviour. It has been widely used to gain insight about automobile operation, aviation web searching, reading, drawing, medical surgery, energy, mining, offshore, and the effect of depictions of healthy and unhealthy foods on children. Among these, automobile and aviation are the two frequently studied fields with a wide.

range of research applications. Studies in these areas have focused either directly on safety or mental testing of drivers/pilots. Those focused on safety measure hazard detection, steering, automated driving, luminance by drivers; and landing , conflict detection , air traffic control by pilots. Mental tests address mental workload, and fatigue. Results of eye-tracking studies show that human error causes most accidents. With respect to automobiles, this reflects the fact that driving virtually always consists of a series of complex behaviours, such that deviation from intention, other drivers' expectations, or desirability may cause severe injury and even death. Similarly, human error in aviation is also critical; it can lead to catastrophic consequences that passengers have a slim chance of surviving. In addition to eye tracking, researchers have studied human error by means of electroencephalography and electrocardiography. Among these, eye tracking is considered one of the most effective if correctly recorded, because human eyes are responsible for obtaining 70% of information humans take in. When paired with rational analysis and visualization methods, eye tracking can support significant engineering improvement. Human error also affects marine operations. The growth of demanding marine operations, such as offshore petroleum extraction, subsea pipeline deployment, and wind turbine installation, has increased the threat human error poses to the safety of people and property. Attempts have been made to use eye tracking to assess marine operations, but systematic instructions for using the method and conducting experiments and assessing its effectiveness remain sparse. There are similarities between automobile, aviation, and marine operation in terms of research topic, experimental design, and procedure in simulator. This suggests eye-tracking methods for marine operation can be developed based on evidence of the approach's utility in automobile and aviation operation. Fig. 1 shows the concept scheme of our work. Methodology and experiment are the two concerns for knowledge transfer. More specifically, efforts have been made to identify regions of visual stimuli, that is, areas of interest (AOI) that draw the human eye. Likewise, analysis is conducted according to methodology from experimental

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design to experimental procedure development. Table I lists the terminologies frequently used in implementations of eye tracking.

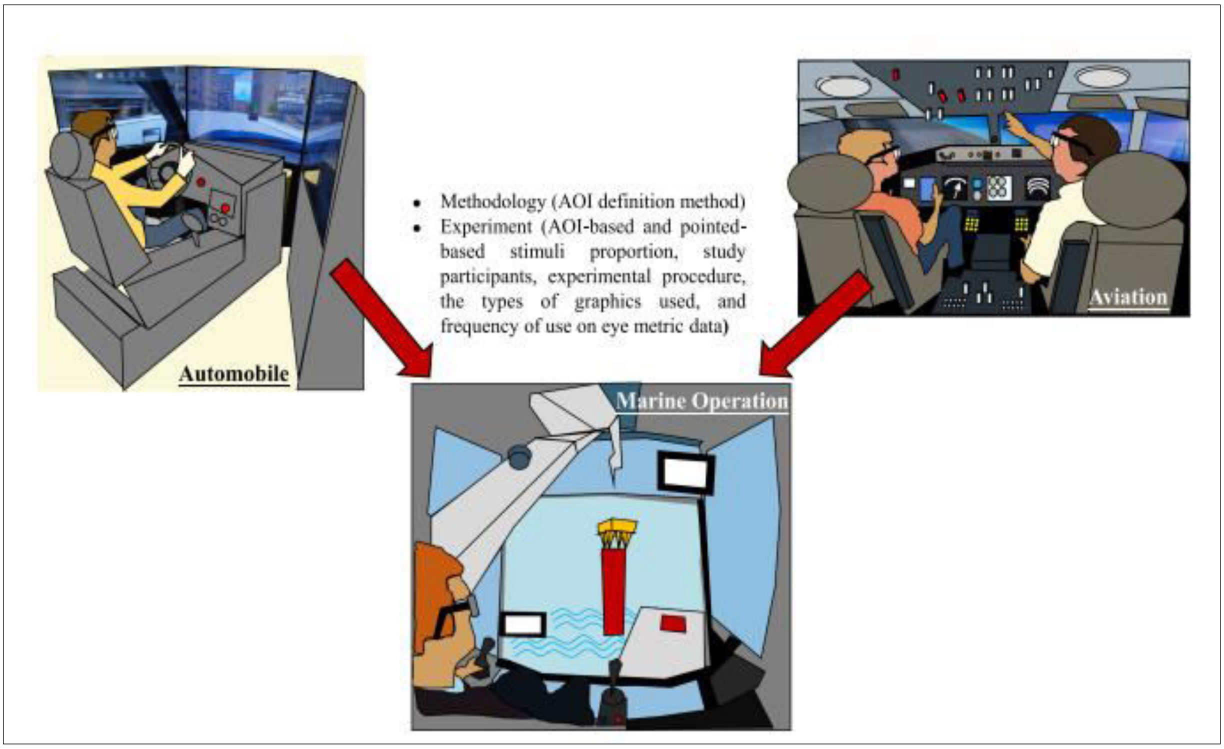


Fig: Transferring eye-tracking methodologies and experiments to marine operation from automobile and aviation research.

The objective of this work is to evaluate the eye-tracking applications in automobile and aviation in order to transfer knowledge from these applications to marine operations as a way to better comprehend human error. The rest of this article is organized as follows. Section II provides the literature search approach and the categorization scheme used. Section III introduces the state of the art of the current AOI definition methods. In Section IV, the experimental design and procedure of eye tracking in automobile and aviation are analyzed and discussed. Section V offers guidelines on the selection of the AOI definition method, as well as experimental design and procedure in marine operation. Section VI concludes the article.

## II. RELATED WORK

Papers reviewed here were published between 2010 and 2020, all have the keyword listed in the figure in the title or abstract. Further exclusions eliminated papers that did not provide the full experiment and qualitative analysis.

1) AOI-Based Stimuli and Point-Based Stimuli: Several papers focus on these types of stimuli. Andrienko et al. [1] termed such papers “AOI focused” and “movement focused,” while Blascheck et al. [3] called them “AOI based” and “point based.” Papers that examine eye movements in relation to AOIbased stimuli focus on the transition and relation of AOIs the researchers define [3]. Papers that examine point-based stimuli use eye movement as the primary. In both cases the focus is on transitions between the spatial or temporal order of the eye-tracking data [1].

2) Static and Dynamic Stimuli: Static stimuli include static visualizations and pictures [2]; they do not change [3]. Dynamic stimuli are changeable, such as videos projected in the simulator or, in real-world scenarios, the view out the window and in the head-up display.

3) Temporal, Spatial, and Spatio-Temporal Visualizations: Blascheck et al. define graphical representations of data visualizations as temporal, spatial, or spatio-temporal [3]. Temporal visualizations are often time-series plots meaning time is the parameter on one axis. Spatial visualizations focus on coordinates of the gaze or fixation in space. Spatio-temporal visualizations show both temporal and spatial aspects of the data [3].

4) Stimulated Scenario and Real Scenario: The research theme, objective, cost, and other conditions will dictate whether measures are conducted in a simulated scenario, a real scenario, or both. Simulated experiments typically occur

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in a driving or flight simulator, which have been well developed in recent years. It has been widely used to gain insight about automobile operation [4], [5], aviation [6].

5) Expert-Novice and Nonexpert-Novice: Automobilerelated and aviation-related studies that use eye tracking can either compare experts and novices or use only experienced participants to study the influence of experience and expertise on eye movements. Such studies can be used to improve training programs for novices and for [7], web searching [8], reading and drawing.

## III. Proposed Work

An attention map, also called a fixation map or a heat map, can also be an alternative way to define AOIs. Creating an attention map involves two main steps: Cutting off the peak of the Gaussian landscape model and taking the selected area as the defined AOIs. Van der Laan et al. used this method to define AOIs by manually deciding the height when they cut the peak of their attention map.

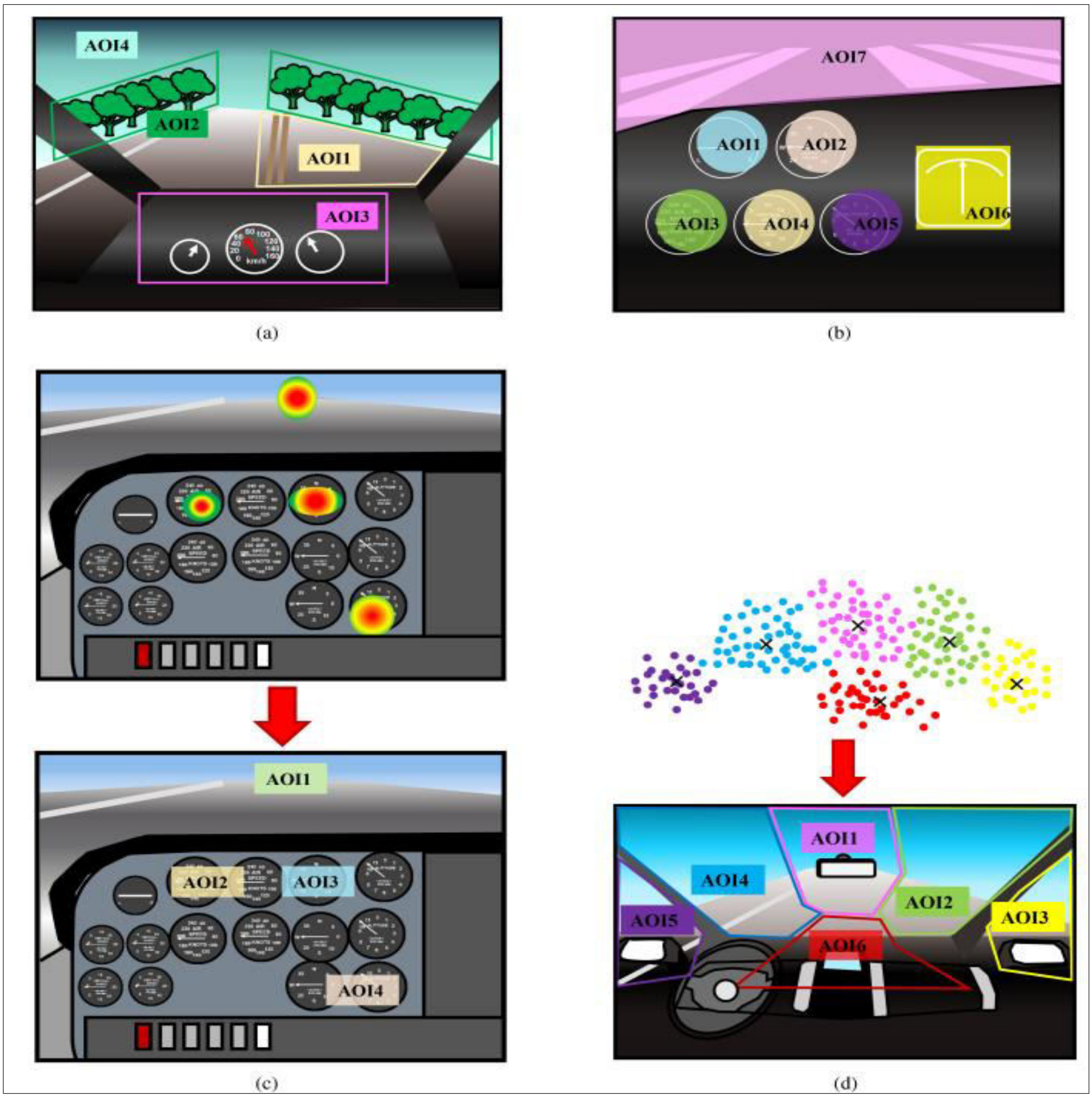


Fig: Typical AOI setting definitions determined by (a) experts (adapted from [32]), (b) generation from stimulus (adapted from [68]), (c) attention map (adapted from [40]), and (d) clustering algorithm (adapted from [75])

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Conditions: The attention map can be used for any study, but its main advantages emerge when other approaches are not available, such as when the stimulus of interest has no clear separation boundaries. When no similar research that might guide the selection of stimuli exists, attention maps offer a potential solution. Data Preprocessing: For studies that use the attention map defined method, experimental data are usually preprocessed by correcting the eye-movement data. Such data can be mistakenly recorded, and hence manual correction is needed. The manual correction is usually undertaken by checking and correcting the recorded coordinates of the eye-movement data based on the experimental data frame by frame. Then initial data is divided into multiple datasets. Processing: In this method, first the attention maps of the participants are plotted based on the obtained data, and then these maps are overlapped into a new attention map. Through comparisons of all study participants' maps, the density boundaries emerge and determine the shape, margin, and size of the AOIs. The author used attention maps to define AOIs in order to study the eye behavior of the drivers or pilots. Fig. :(c) shows the typical AOI setting using an attention map defined method. Attention maps are built through the experiment instead of being used as a condition of the experiment. The AOIs are defined based on the obtained attention map. They are indicated with different colors to show their priority sequence according to the eye-movement density.

## IV. ALGORITHMS USED

As with the attention map method, clustering algorithms define AOI after eye-movement data are collected. Clustering algorithms are used to assign gazes or fixations into subsets in a systematic and logical way. In most circumstances, scholars divide the gazes or the fixations by spatial coordinates.

The K-means clustering method is one of the most frequently used methods. This involves clustering n data points into k clusters based on counting the point to the spatially closest cluster and revising the centroid of the points. Another type of clustering methods, such as the mean-shift algorithm, is based on density of data points. The core of the algorithm is to iteratively shift points to a higher density area, then cluster into AOIs. Gu et al. used a mean shift algorithm to group fixation points into clusters.

Other clustering algorithms exist. For example, Goldberg and Schryver presented an algorithm to find fixation-like spatial clusters, the minimal spanning tree.

**Conditions:** Clustering algorithms are most often used to define AOIs under circumstances similar to those in which attention maps are used (the conditions described in Section III-C), but the clustering method is usually used when the AOI definition emphasizes clustering.

**Data Preprocessing:** The data preprocessing method described in Section III-C applies to the clustering defined method as well as in cases when attention maps are used. Initialization: Defining AOIs by clustering algorithms frequently requires initialization of the parameters. Different algorithms require initialization of different parameters. For example, in a typical K-means clustering algorithm method, the initial parameters are usually central coordinates for datasets. Hyperparameters, such as the cluster number k and the maximum iteration number n, can also be initialized; Xu et al. initialized the successive iterations for a given cluster center and derivation parameter P in his research using the improved affinity propagation algorithm. These numbers can largely influence the clustering result and the performance of the clustering.

**Iterations:** Iteration is an important part of the clustering algorithm method. A machine must optimize the clustering result step by step based on the selected clustering method and the hyperparameters such as the cluster number k, and the maximum iteration number n, etc.

**Validation:** The clustering result needs to be validated because it is not always satisfactory, e.g., not consistent with research expectation. If the clustering results do not align with the requirements that the defined AOI number and AOI distribution show consistency with driving common sense, the solution usually is to change the initial value or some other parameters, and repeat the clustering procedure until satisfactory results are achieved . Fig. 4(d) shows the typical AOI setting using a clustering algorithm method. The AOIs are defined based on the clusters obtained from the selected algorithms.

## V. SIMULATION RESULTS

First, the experiment is usually conducted in a simulator. Then, research topic, experimental design, and procedure such as study participant are also similar across these fields. This makes it easier to transfer the knowledge gathered here about automobile- and aviation-based studies to marine operation studies. The sections below describe how the knowledge assembled above about methodology and experimental design can be transferred to eye tracking of marine operators, addressing the AOI definition method and experimental design, and procedure. A case study on marine operation follows, that describes the impact of such knowledge transfer.

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For AOI definition, the whole crane lifting operation was divided into several stages and AOI was defined for each stage. Fig. shows how the AOIs were defined in the case study. For one segment in a crane lifting operation, the AOIs were defined based on a combination of expert opinion and an attention map. The former was obtained through a questionnaire the participants completed, and the attention map was established by the experts after the study area was determined. Then the defined AOIs were validated through the feedback of the expert participants and the analyzed data.

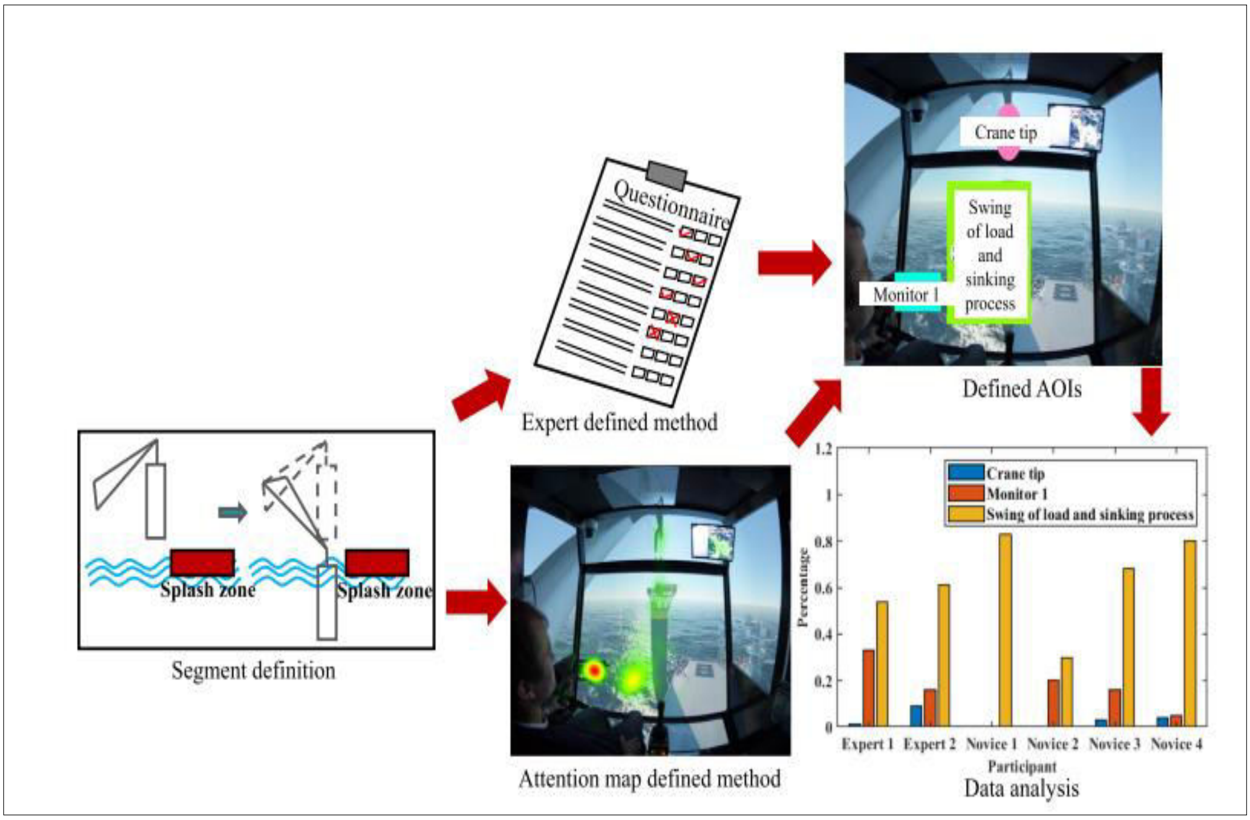


Fig: Flow chart of how the AOIs were defined and the experimental procedure used

## VI. Conclusion and Future Work

In this work, the recently published papers using eye tracking in automobile and aviation were surveyed and categorized to evaluate the application of this method in these two areas. The objective was to seek potential knowledge transfer to marine operations for better studying of human error. The surveyed papers were categorized according to the defined characteristics and were evaluated based on AOI definition method, experiment design, and procedure. The result suggests that expert-defined and stimulus-generated AOI definition methods are favored over other methods. The analysis also extracted aspects of experiment design and procedure. The implications for eye tracking in marine operations were extracted based on the evaluation of the surveyed papers in automobile and aviation. The instruction as to how to apply an AOI definition method for specific scenarios in marine operation was proposed; at the same time, in experimental design and procedure offered a guideline on AOI-based and point-based stimuli selection, experimental procedure design, participant selection, visualization method selection, and eye metric data selection.

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