International Co-operation on Theories and
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Understanding Urban Environmental Impact on Cyclist Visual Load: A Machine Learning Application

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INTRODUCTION

In the pursuit of improving urban road infrastructures and ensuring traffic safety for all road users, the safety of cyclists is paramount. With the growing number of cyclists and related traffic incidents, there is a need for a deeper understanding of cyclist behavior, including their visual perception and control strategies. Despite extensive research on urban cycling safety, few studies have effectively integrated eye-tracking with advanced machine learning techniques to quantify visual workload in real traffic conditions. This study introduces an innovative application of XGBoost machine learning algorithms to analyze eye-tracking and spatial data in urban cycling environments. This method allows for a systematic examination of how urban environments influence cyclists' visual workload and decision-making processes.

METHODOLOGY

This research utilizes a comprehensive approach to analyze the impact of urban spaces on cyclists' visual workload in real-traffic settings. The methodology integrates eye-tracking data, spatial data in geographic information system (GIS) and kinematic data from Global Navigation Satellite System (GNSS) and employs the XGBoost machine learning algorithm for data analysis.

Data Collection and Preparation

The experiment was conducted along a bike lane in a urban area, under real traffic conditions. Cyclists used an instrumented bicycle equipped with a GNSS system that records position, speed and heading at a 4 Hz frequency, and two front cameras to capture the 180° field of view. In addition, participants wore a head-mounted eye tracker consisting of two internal eye cameras to record gaze and a front scene camera that captures the surrounding environment from the cyclists' perspective. Additional spatial data was sourced from OpenStreetMap (OSM) in Quantum GIS (QGIS) environment, providing detailed information on location features like road infrastructure, urban characteristics, and environmental surroundings.

Object Segmentation and Semantic Classification

For the gaze data analysis, an advanced computer vision algorithm was developed to merge the eye and scene camera images into a single video displaying the "image scene" with the gaze position. Objects of interest were classified into semantic classes, associating gaze data with the specific objects the cyclist was looking at. The nineteen semantic classes selected to be identified within the cyclists' field of view are: road, sidewalk, building, wall, fence, pole, traffic light, traffic sign, vegetation, terrain, sky, person, rider, car, truck, bus, train, motorcycle, and bicycle. Eye movements can be categorized into fixations and saccades. Fixations are periods of stable eye movement to focus on an object, while saccades are rapid eye movements between fixations. Fixations with durations over 200ms are considered for analysis, with longer fixations indicating higher workload. The number of fixations reflects the processing of data and visual workload.

OpenStreetMap Data

We extracted detailed environmental and infrastructural data from OpenStreetMap (OSM). This step involved querying OSM in QGIS for geographical features, which are: road layouts, bike lane presence, and traffic signage within the study area. Utilizing custom scripts, we programmatically retrieved and processed this data to align with the GNSS coordinates collected during the experiments.

GNSS data

Cinematic data, like speed and heading, was collected with a multiband GNSS receiver coupled with 6-axis inertial sensor to improve the accuracy of position also during GNSS interruptions and the frequency acquisition up to 4 Hz.

Data Integration

Data from OSM is extracted to QGIS, an open-source GIS tool, overlay cyclists' routes with accurate, up-to-date urban geography, enabling precise correlation between cyclists' gaze behavior and the surrounding urban environment. This process involved aligning the time-stamped eye-tracking data with the corresponding GNSS coordinates and kinematic data, ensuring accurate mapping of the cyclists' position and gaze onto the urban landscape [3].

Model Development

XGBoost, short for Extreme Gradient Boosting, stands out as a robust machine learning algorithm renowned for its ability to efficiently handle large and intricate datasets through a gradient boosting framework. Its remarkable computational efficiency and accuracy render it particularly suitable for our study. We leveraged its capabilities to effectively capture the nuanced relationships between urban spatial characteristics and cyclists' visual workload and behavior. We derived features for the machine learning model from an integrated dataset comprising Eye tracker, GNSS, and OSM data. These features served as explanatory variables, while the target variable was a composite measure of visual workload derived from fixation durations and the count of fixations.

RESULTS

As the study is currently ongoing, comprehensive results are yet to be fully analyzed and will be ready for the conference. Preliminary results show the capability of the model to extract feature relative importance highlighted the urban space characteristics and cyclists' interactions with the semantic objects in the cyclists' field of view, which have the greatest impact on visual workload and Prediction Performance evaluates the model's ability to estimate visual workload based on the input features.

CONCLUSIONS

The integration of visual and spatial data, along with their analysis using the XGBoost algorithm, will provide valuable insights into how visual workload helps identify situations where cyclists may experience increased cognitive load.

In future applications, this model can be used to visualize predicted visual workload levels across different urban space typologies and environmental conditions in simulated scenarios to identify hotspots or critical areas where cyclists experience heightened visual workload.