Eye in the Sky: Predicting Air Traffic Controller Workload through Eye-tracking based Machine Learning

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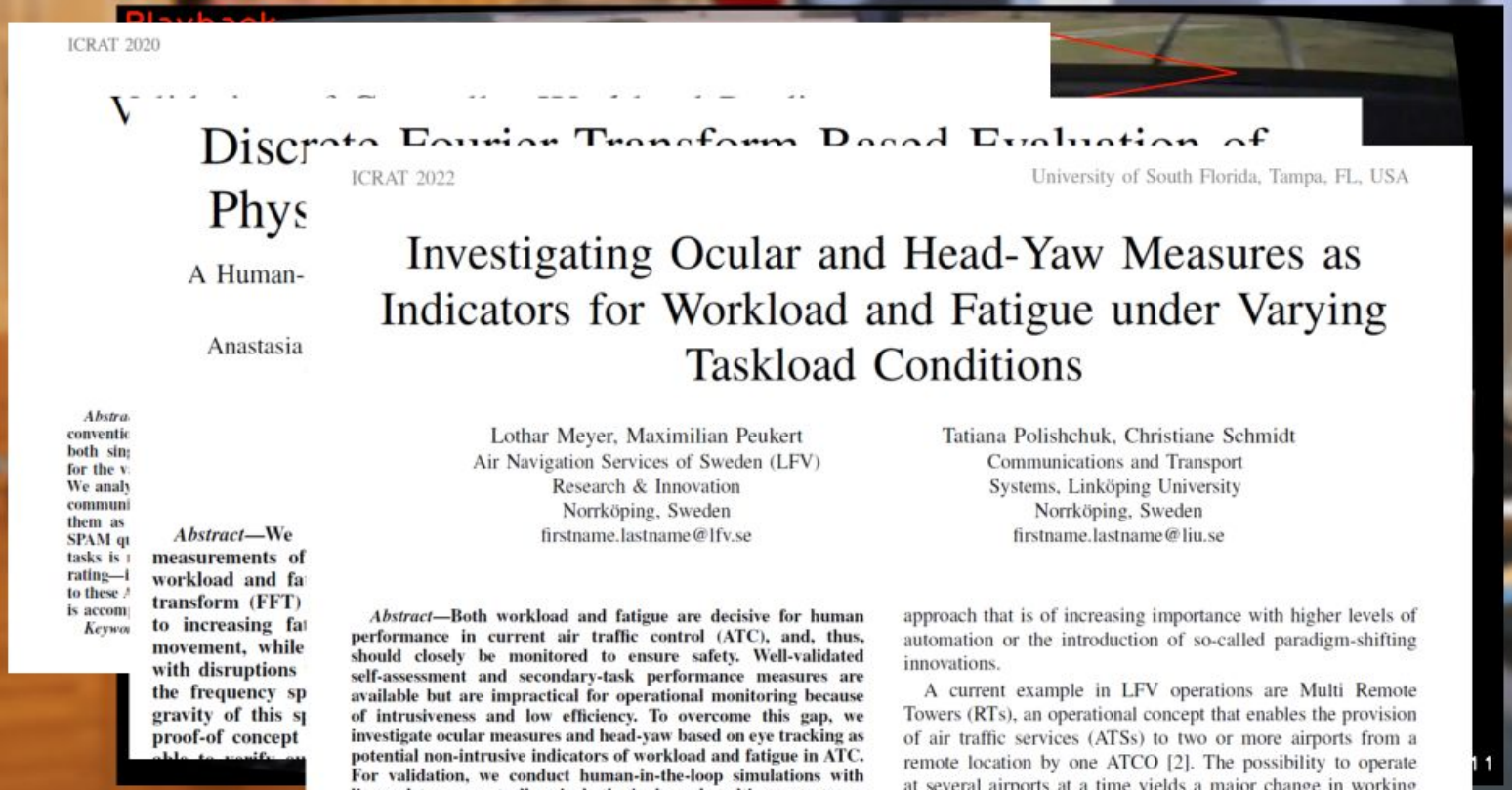
LFV

Ocular and Head Movements for Workload Measurement



ICRAT 2020

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ICRAT 2022

University of South Florida, Tampa, FL, USA

Investigating Ocular and Head-Yaw Measures as Indicators for Workload and Fatigue under Varying Taskload Conditions

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Abstract—**Both workload and fatigue are decisive for human performance in current air traffic control (ATC), and, thus, should closely be monitored to ensure safety. Well-validated self-assessment and secondary-task performance measures are available but are impractical for operational monitoring because of intrusiveness and low efficiency. To overcome this gap, we investigate ocular measures and head-yaw based on eye tracking as potential non-intrusive indicators of workload and fatigue in ATC. For validation, we conduct human-in-the-loop simulations with licensed tower controllers in both single and multi remote tower**

approach that is of increasing importance with higher levels of automation or the introduction of so-called paradigm-shifting innovations.

A current example in LFV operations are Multi Remote Towers (RTs), an operational concept that enables the provision of air traffic services (ATSs) to two or more airports from a remote location by one ATCO [2]. The possibility to operate at several airports at a time yields a major change in working

Simulation-Study Setup

- 18 licensed ATCOs
- ACC Malmö, Topsky, sector Whiskey
- 3 runs per ATCO (light/moderate/heavy task load scenarios)
- 54 simulation runs in total, each lasted 35-45 minutes
- Verbal WL self assessment on the CHS every 3 minutes
- Camera and a screen-grabbing system
- Large primary screen for radar + two smaller screens
- Eye tracking: Smart Eye XO
- EEG: Mindtooth

Simulation-Study Setup (cont.)

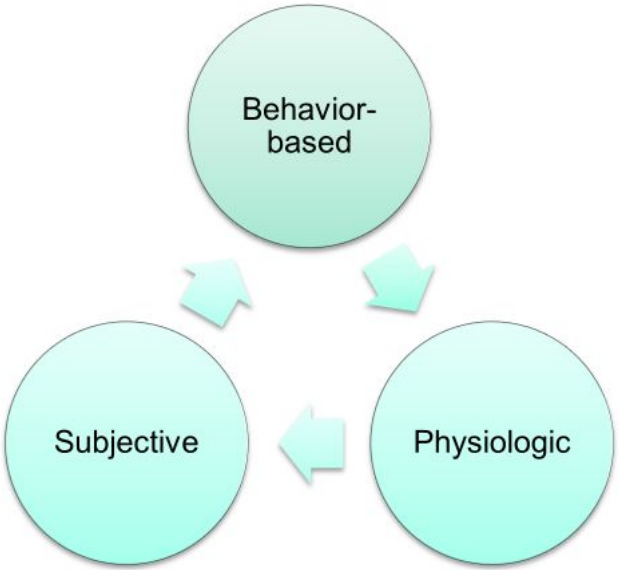
Simulator-Based Data Collection

- Ocular and Head-Yaw Measures - Smart Eye XO
  - Two infrared cameras
  - 250 Hz sampling rate
  - Blink Amplitude, Blink Speed, Pupil Diameter, Saccade, Fixation, Amplitude and Speed of Eyelid Closing and Opening, Head Rotation
  - Up to 1.5 degrees of head rotation accuracy and 0.5 degrees of gaze tracking accuracy (compatible with eyeglasses)
- EEG data - Mindtooth
  - Wearable and portable semi-dry EEG device
  - 125 Hz output data rates
  - Optimised to monitor basic cognitive and emotional states (Workload, Vigilance, Stress)

Adapted Cooper-Harper Scale

Rating	Evaluation	Question for Evaluation
1	No problems, desirable	Is the situation solvable without major Disturbance?
2	Simple, desirable	
3	Adequate, desirable	
4	Small, but disruptive "delays"	Is the situation solvable by capacity-reducing measures?
5	Medium loss of capacity, which can be improved	
6	Very disruptive, but tolerable difficulties	
7	Problems to predict development of traffic situation	Is the situation solvable if the ATCO works with a reduced situational awareness?
8	Problems in information processing	
9 9	Problems in information reception	
10	Impossible	

Multivariate Approch



Reference Workload
- Cooper Haaper
- EEG Workload (Mindtooth Neurometric)

Reference Taskload
- Simulated Traffic (Work Condition)

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Scenario Design Verification

Event	Task	Score
A/c is about to enter the sector, a/c crossing the sector	Acceptance + monitoring	2
A/c is about to leave the sector	Transfer	1
Conflict type 1: cruise-cruise, conflict due to overtaking	Determining conflict type 1 + taking decision how to solve + monitoring	5
Conflict type 2: cruise-climb, cruise-descent, climb-descent	Determining conflict type 2 + taking decision how to solve + monitoring	7
A/c landing, a/c climbing, conflict	Instruction to pilot (clearance / vectoring /level change / speed control)	4

The results for the first participant: 142, 221, and 538 for light/moderate/heavy task load scenarios

Machine Learning Approach

Features

15 eye-tracking and head movement variables ⇒ 61 statistical summary features

Left/right Blink Amplitude and Speed, Pupil Diameter, Amplitude and Speed of Eyelid Closing and Opening, Saccade, Fixation, Head Heading, Pitch and Roll

mean, standard deviation, median, minimum, maximum, total number and duration

Labels

- Cooper-Harper Scale scores
- EEG variable Workload

Classification Tasks

CHS scores stats:

- 1 - 52%
- 2 - 23%
- 3 - 18%
- ≥ 4 - 7%

	Low WL	Medium WL	High WL
CHS	1	2-3	≥ 4
EEG	below 52nd percentile	between 52nd and the 93rd percentiles	above 93rd percentile

Machine Learning Models

- Logistic Regression (LR)
- Decision Tree (DT)
- Random Forest (RF)
- Support Vector Classifier (SVC)
- Histogram-based Gradient Boosting Classification Tree (HGBC)

Additional ML techniques:

- class weights
- hold-out strategy
- feature normalization prior to the model fitting stage for training and test set separately
- hyperparameters tuning using Randomized Search with k-fold Cross Validation

Model evaluation metrics: *accuracy* and *macro F1-score*

Results and Conclusions

- CHS labeling
  - 3 classes: accuracy - 0.84, F1-score - 0.72 (HGBC model)
  - binary: accuracy - 0.93, F1-score - 0.83 (SVC model)
- EEG labeling
  - 3 classes: accuracy - 0.86, F1-score - 0.77 (HGBC model)
  - binary: accuracy - 0.96, F1-score - 0.84 (RF model)
- We showcase a considerable potential of machine learning techniques in predicting ATCOs workload solely based on eye-tracking and head-movement characteristics
- Possible Future Work: subject-independent and subject specific approaches, investigating various feature selection and combination techniques
- Ref.: A. Lemetti, L. Meyer, M. Peukert, T. Polishchuk, C. Schmidt, H. Alpfjord Wylde Eye in the Sky: Predicting Air Traffic Controller Workload through Eye-tracking based Machine Learning. DASC 2024 (accepted)

Thank you!

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