Masterarbeit Nr. 100 - 2023

Measurements of Physiological Parameters in Flight Simulator Studies for Stress Detection and Analysis through Deep Learning Applications

Assignment:

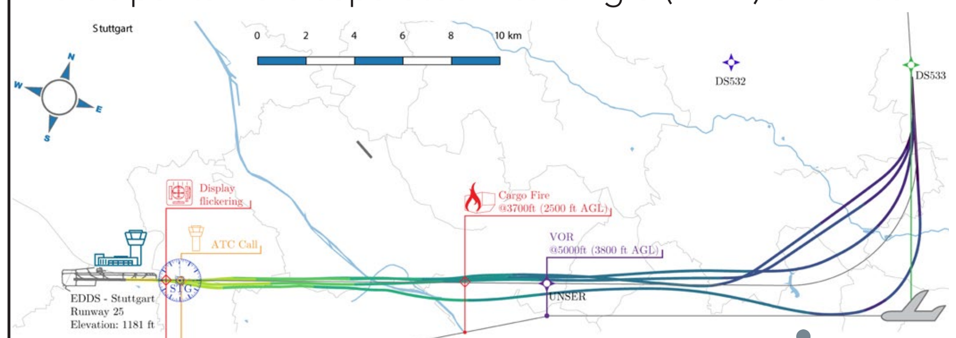
The goal was to measure physiological data of pilots under stressful flight scenarios. Based on these data a deep learning model for real time determination of stress levels based on ECG was to be created.

1. Flight Simulator Studies

In order to acquire viable data for stress detection, physiological data was measured during two flight simulator studies. Those took place in the A320 flight simulator of the Air Vehicle Simulator (AVES) at the DLR in Brunswick, Germany, see images below.

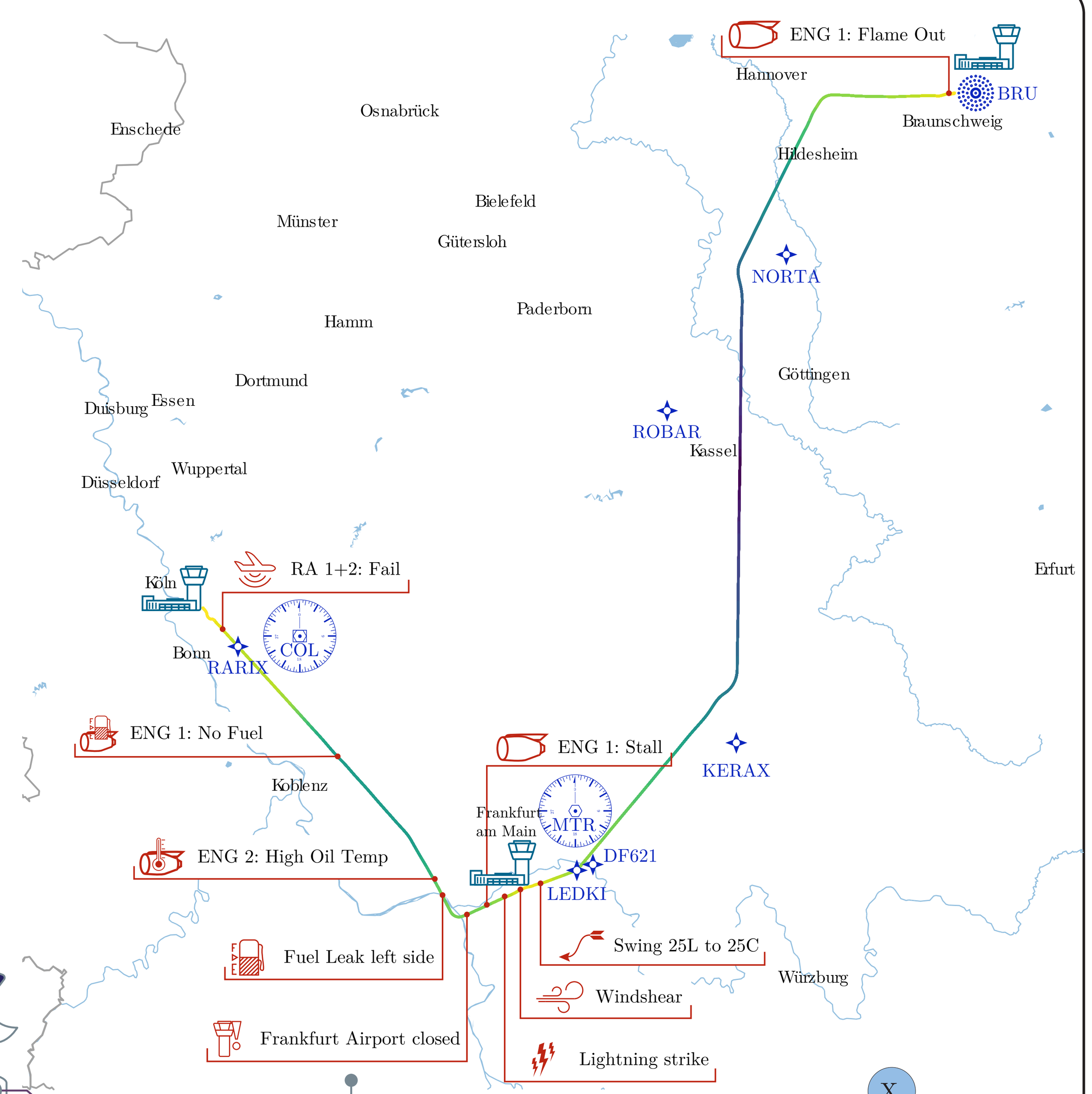
1.1 Single Pilot Operation Study

The Single Pilot Operation (SPO) study took place in April 2022 with 24 participants as part of another Master's thesis. Pilots needed to perform 5 different approaches while flying manually and facing different failures. Participants were separated into Single (n=14) and Dual Pilot Operation (n=10). As an example, scenario 2 is shown on the lower left. During the scenarios, a galvanic electrocardiogram (ECG) was recorded. After each scenario participants filled out a stress level form as well as the NASA TLX questionnaire.



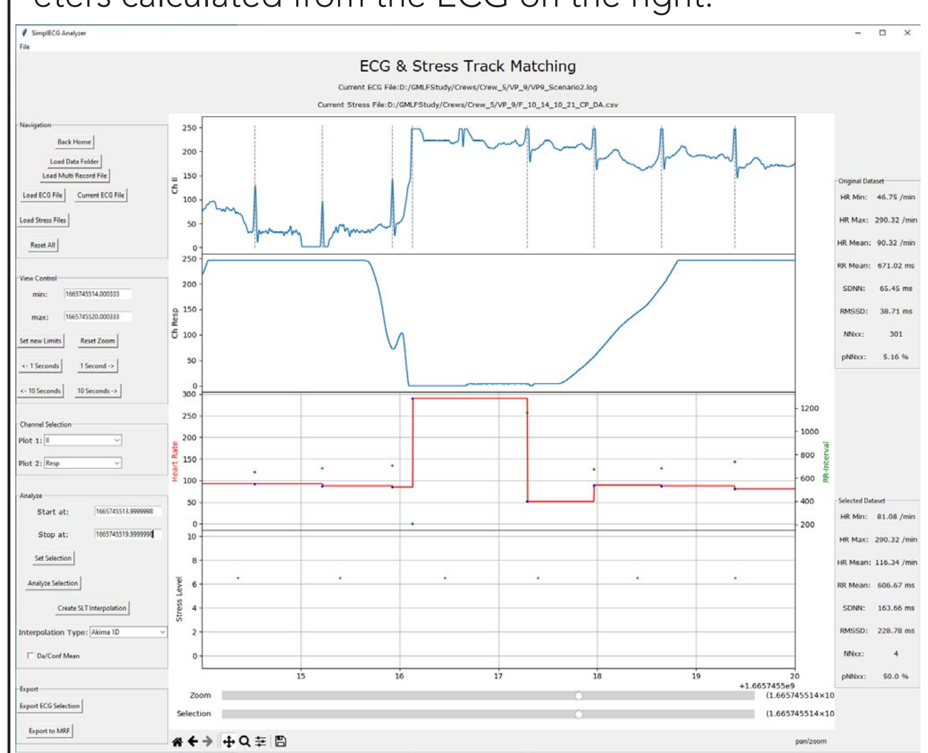
1.2 Limits of Human Performance Study (LoHP)

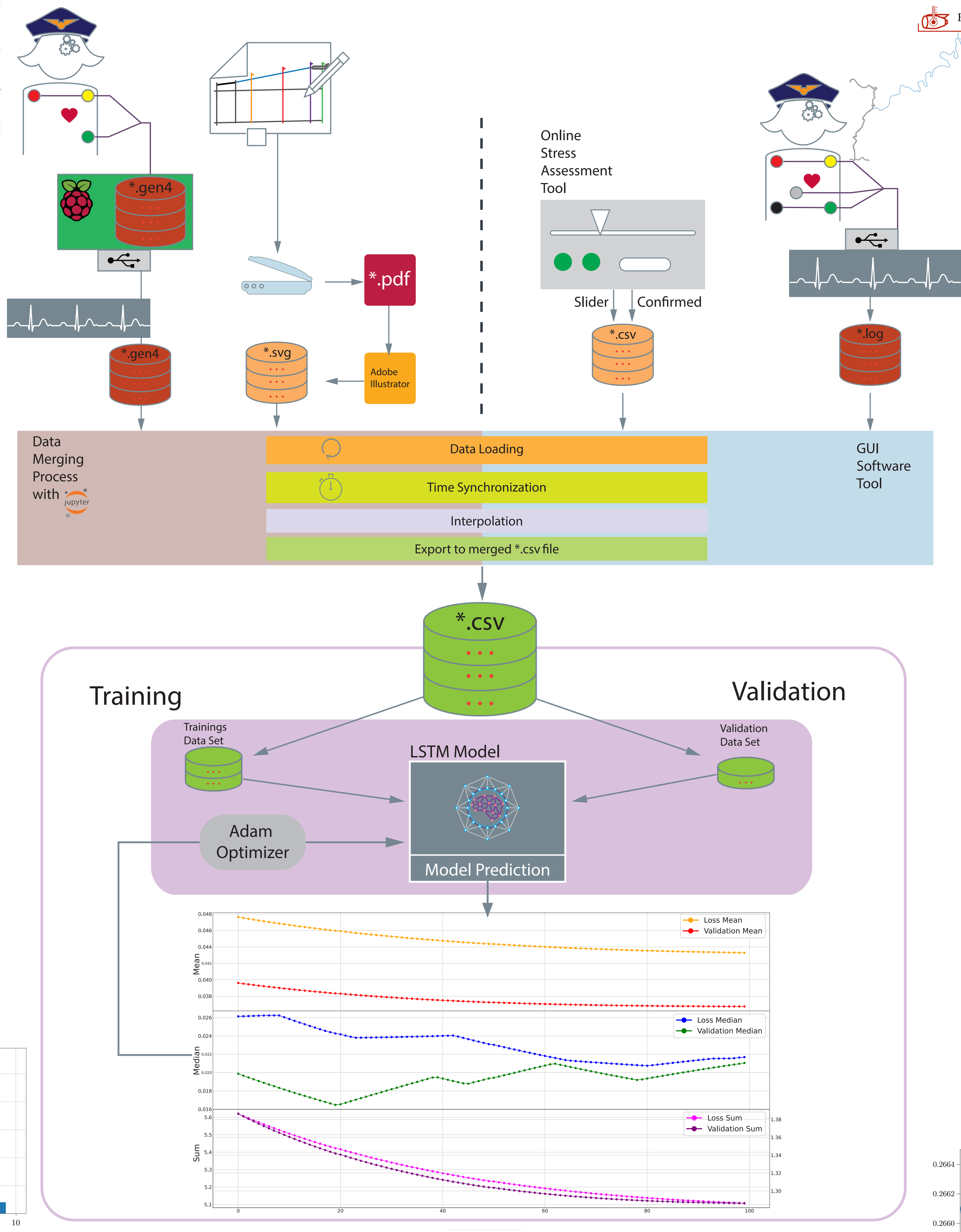
Based on the results of the SPO Study this second flight simulator study was created and conducted in October 2022. The main goals were to measure more physiological data, getting a higher quality of stress level feedback from participants, and triggering more stress for a longer period of time. A baseline scenario with no failures was flown first where flight crews had the opportunity to familiarize themselves with the simulator. In the second stress scenario various failures and stressors were simulated in order to trigger stress, see picture on the right. In this study 9 flight crews participated, consisting of 5 Captains and 13 First Officers with valid A320 type rating.



2. Analysis Software

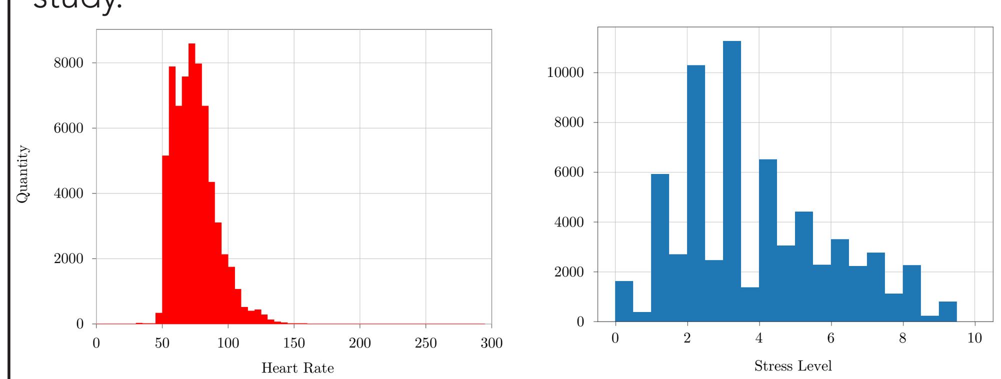
In order to analyse and merge the raw collected data into one time synchronous file format, various software tools were created. In order to speed up the process for the LoHP study's data SimplECG was designed. The interface with a movement artifact example is shown in the image below: SimplECG tool with the control panel on the left; ECG, heart rate and stress level plots in the middle; and heart rate variability parameters calculated from the ECG on the right.





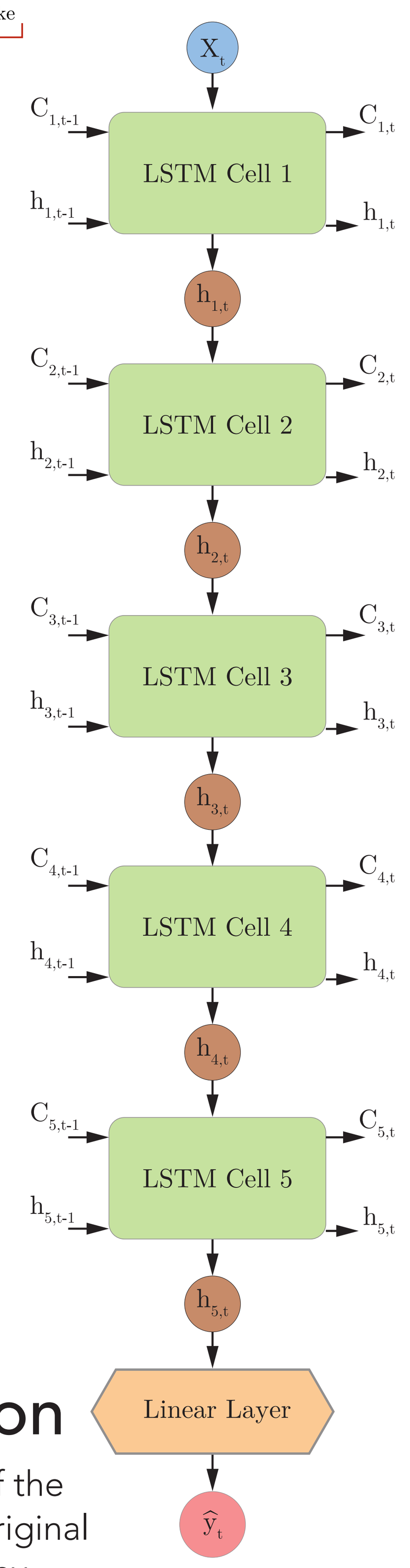
3. Data Distribution

Distribution of heart rates (left) and stress levels (right) from all participants of the stress scenario of the LoHP study.



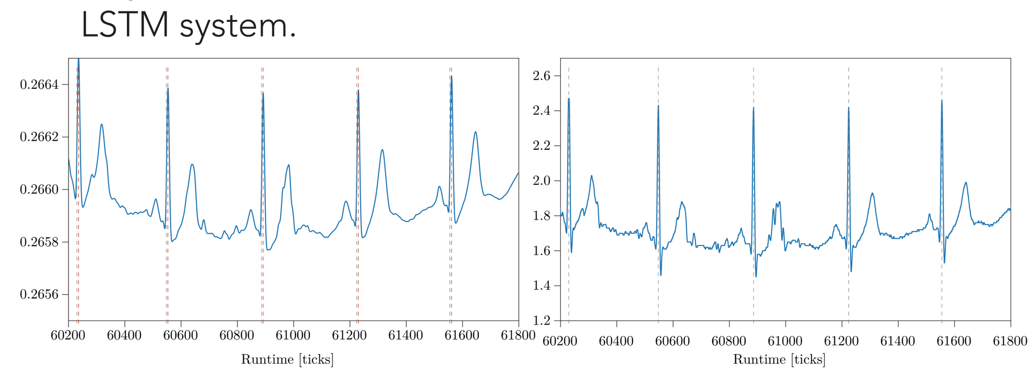
4. LSTM System

LSTM is a type of recurrent neural network (RNN) that is well-suited for analysing time series data. The benefit is that they can effectively capture long-term dependencies and patterns in the data. This is because LSTMs are designed to maintain a memory of past inputs, which allows them to better understand how past inputs relate to current and future outputs. The system used in this thesis consists of five stacked LSTM-cells with a linear layer at the end to reduce the last LSTM layer to a single value output, as shown on the right. The objective was to use a deep enough yet simple first architecture that can be further improved.



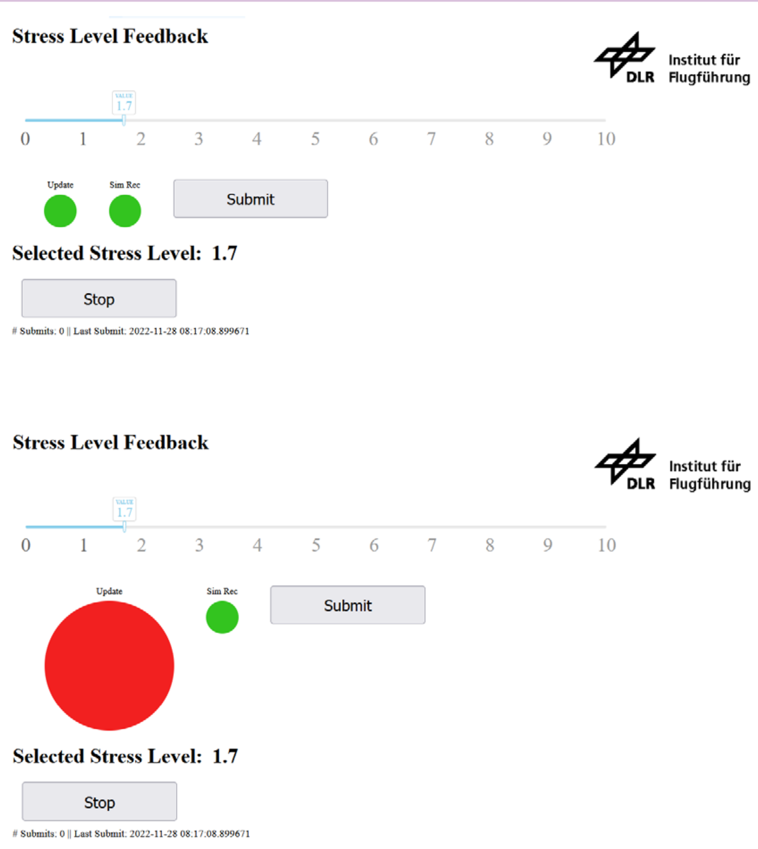
5. Model Prediction

The output (right image below) of the found LSTM system mimics the original input (left image) with a small delay. This indicates that more abstraction needs to be done. This can be achieved by adding other types of layers (e.g. fully connected and/or convolutional) before and after the LSTM system.



Online Stress Assessment Tool (OSAT)

OSAT is a tool to track stress in pilots and was used first during the LoHP study. It utilizes a slider asking participants to assess their momentary stress level on a scale between 0 (resting) and 10 (maximum individual stress). After selecting the corresponding stress level on the slider by either pressing or sliding, the participant needs to submit this value by pressing on the "Submit" button. After one minute without submission the update indicator turns red and becomes larger, see lower image on the right. After another minute without update the stress slider increases by 0.1 every 2 seconds. Submitting a stress level manually resets this to the initial view.



6. Conclusion

This thesis demonstrated the feasibility of designing simulator studies for pilots, developing a novel way to measure stress during flights, and using a flight simulator to record physiological data. Software tools were created for data acquisition, visualization, and processing. An LSTM system was trained and evaluated with the acquired data. While some issues remain, solutions are on the horizon, and with modifications, the setup could become a viable stress detection system.

Source Code and Data:

https://github.com/0Patrice/StressDetectionInFlightCrews

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