The Sixth Sense

of an Air Traffic Controller

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Motivation: Human Factors Improvement

- Humans are a limiting factor – if not sufficiently supported
- Drastic improvements should be achievable utilizing more “human senses”
  - More bandwidth between human and machine
  - Possible safety net through comparison of different “senses”
- Prediction through subconscious body language
  - Can we depict repetitive patterns?
  - Can we predict “good” and “bad” decisions measureable?
Introduction

- When working with an ATM system can the user’s body language/choices provide valuable cognitive information

- To uncover hidden patterns that will allow us

- To distinguish between “good/bad” (erroneous) inputs/interactions and ultimately avoid mistakes /bad decisions

EEC - Eurocontrol Experimental Centre courtesy of Eurocontrol
Experiment Set-up
Experimental Workflow

Overall Experiment Briefing (incl. Operational)

Start of Experiment

A_Pre-Questionnaire

Recording of data  Run Exercise  B_Supervisor Observation (Observation List)

C_Post-Questionnaire

D_Debriefing

Overall Experiment Debriefing
Our Hypothesis

The algorithms of the 6th Sense Module should be tested by answering the following hypotheses:

**Hypothesis H1:** It is possible to detect situations in which the operator tends to make bad decisions by analysing user-input and user-tracking data

**Hypothesis H2:** The module is able to identify good and bad workflow patterns.

Workflow patterns in H2 are sub-sequences of actions the controller performs. These workflow patterns might vary between controllers. H1 refers to the decision a controller makes in a single step of the workflow.
Experiment Set-up

- **Exercise 1**
  - Sensor hardware tested, data acquisition pipeline established

  - Professional air traffic controllers and first real test of setup

- **Exercise 2 part 2 (05.02.2015) – 4 ATCOs**
  - Observer and supervisor notes integrated in the framework
  - Environmental sensors added
Experiment Set-up

Scenario

- **Hamburg Airport Tower Scenario:**
  - Simulation prepared for approx. 60 min.
  - Arrivals are automatically simulated until touchdown. (no change of route)
  - Departures are controlled until take off.
  - No Runway change is foreseen within the simulation
  - Taxiway Routes can be selected by the operator.

- **Configurations during the experiment:**
  - Arrival Runway: 23
  - Departure Runway: 33
  - Arrivals: 31 flights
  - Departures: 27 flights
Experiment Set-up

Scenario

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Any other workflow would be fine, too
- Area Control
- TMA
- Airport
Experiment Set-up

Working Position

- Simulator Position
  - Voice Recognition
  - Server Components
  - Simulator
  - RWY Controller Position
  - Pilot Simulation

- Ground Position
  - Ground Controller Position
  - AMQ Broker
  - MySQL Data Logger
  - Kinect
  - Eye-tracker

- Observer Position
  - Video / Screen Capturing Questionnaires
Experiment
From Plan to execution
Experiment

From Plan to Execution

Areas of Interest (AOI) in Ground Control Simulator
Experiment
From Plan to Execution

Observation & Debriefing
The collected Data

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Simple Metrics and Data Exploration

- Decision on topics and metrics, ranking
- Based on data availability, completeness, data quality and relevance

- The selected topics were:
  - Mouse
  - Observations
  - Selections
  - Selection and Stress level
  - Voice
  - Workload Metrics
  - Eye Mouse AOI
  - Heart Measurements
A word on Observations

- Observation list created from video recordings
- Side remark for lessons learnt: next time add a self-assessment part
Approach to guide our Analysis

Simple metrics
Approach to guide our Analysis

Simple metrics

Next level of metrics

Simple visualizations
## Approach to guide our Analysis

### Simple metrics (Table 3)

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<td>Error messages</td>
<td>nr. of tasks completed / not completed</td>
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*) includes behavioural metrics not assigned to certain user states due to lack of literature findings
5 General Research Questions

- How to improve the user interfaces usability?
- How to detect main causes that lead to mistakes (e.g., using air traffic info, eye tracker, mouse, heart rate data, body pose)
- What are the hidden data signs that we can incorporate in an automated system to detect and predict
  - the users next actions or to predict
  - when a user is in a high workload situation or is about to make a mistake?
- What are the unknown factors that contribute to higher stress levels or to the lack of situational awareness?
- Can air traffic information be combined with sensor information to improve the detection and classification?
Approach to guide our Analysis

Simple metrics (Table 3)  Next level of metrics (Table 5)  general research questions

Simple visualizations  Ranking Categorization
Approach to guide our analysis

Simple metrics (Table 3) → Simple visualizations

Next level of metrics (Table 5) → Ranking Categorization

general research questions → heavy thinking

Concrete research questions
Results

Highlighting some examples of our findings
Correlation between Heart Rate Variability Data and negative observations
Relation between mouse and eye movements (AOI) and occurrence of errors
Relation between mouse and eye movements (AOI) and occurrence of errors

Period of increase in movements (AOI visited)

Simultaneous decreasing of mouse movements

Decrease in eye movements

Increases in mouse movements

Increase in eye movements

Positive: □ Negative: ■ DiffFromAvgAOI

-147.8 157.3
Correlation of negative observations and difference in number of words/mouse actions:
Sequential Patterns of Interaction Sequences
Sequential Patterns
Summary of Results

- Reductions in mouse movement and increases in the eye movements coincident with the occurrence of negative observations. (Figure 45)

- The HRV together with the reduction in mouse activity, the number of visual UI objects to be managed and the eye tracking AOI frequency and duration provide very good clues for anticipating moments of stress and high workload.

- Direct relations between increase in the number of words used by ATCO and occurrence of negative observations (Figure 50)

- [Correlation between the users head position and negative observations that indicate promising model creation for predictions.]
Conclusion

- Few studies about multisensoric HMIs in safety critical environment available
  - We are at the very beginning with this research!
- Our research should motivate follow up projects
  - We have indications that there are specifiable patterns for similar “situations”.
  - Therefore, it can be assumed that prediction on those patterns is possible.
- Our work proves that both hypotheses are testable – although it was beyond our means with given resources.
Lessons learnt

Next experiments should use more sensors in multiple combinations.

- EEG, Kinect, sophisticated Voice Recognition

More experiments are needed with more and smaller exercises

- …instead of full traffic simulation.

More reliable and distinct qualification of “good” and “bad” needed

- E.g. through self assessment
The End

Questions?