Adaptive Situation Awareness Displays for Multi-UAV Supervisory Control

Florian Fortmann (florian.fortmann@offis.de)
OFFIS - Institute for Information Technology
About us

OFFIS, Transportation, Human Centered Design

Automotive

Shipping

Manned Aviation

Unmanned Aviation

Space

We have expertise in 5 domains
About me

Florian Fortmann

• Research position at OFFIS in the group „Human-Centered Design“
• Interested in intelligent adaptive systems
• First contact with intelligent, highly-automated technical systems in the 80s
First Contact
First Contact

- Automated driving
- Dynamic control transitioning
- Adaptive automation
- Human-machine partnership
- Dynamic adaptation of human-machine interfaces
- Multi-modal human-machine interaction
- Natural interaction
- Observation and assessment of human behavior
- Inference of cognitive state
- Artificial emotional intelligence
Applying **Pilot Models** for Safer Aircraft

- Automated flying
- Dynamic control transitioning
- Adaptive automation
- Human-machine partnership
- Dynamic adaptation of human-machine interfaces
- Multi-modal human-machine interaction
- Natural interaction
- Observation and assessment of human behavior
- Inference of cognitive state
- Artificial emotional intelligence
Overview

• Automation
• Human supervisory control
• Situation awareness
• Adaptive situation awareness displays for multi-UAV supervisory control
• Lessons learned
Automation and Human Supervisory Control
Automation

„Automation is a device or system that accomplishes (partially or fully) a function that was previously carried out (partially of fully) by a human.“ (Parasuraman, 2000)
Simplified information processing cycle
(Parasuraman, 2000)
Today we typically talk about the **automation of highly complex technical systems** which humans could only hardly operate **effectively, efficiently, and safely** without automation.
Human Supervisory Control

What Disney believes it is...
Human Supervisory Control

(Sheridan, 1992)

- **Plan** what task to do and how to do it
- **Teach** the automation what was planned
- **Monitor** the automation executing the task
- **Intervene** if problems occur
- **Learn** from experience
**Human Supervisory Control**

- **Plan** what task to do and how to do it
- **Teach** the automation what was planned
- **Monitor** the automation executing the task
- **Intervene** if problems occur
- **Learn** from experience

(Sheridan, 1992)
Human Supervisory Control

Plan what task to do and how to do it
Teach the automation what was planned
Monitor the automation executing the task
Intervene if problems occur
Learn from experience

(Sheridan, 1992)
Human Supervisory Control

- **Plan** what task to do and how to do it
- **Teach** the automation what was planned
- **Monitor** the automation executing the task
- **Intervene** if problems occur
- **Learn** from experience

(Sheridan, 1992)

05.12.2014  Florian Fortmann – Adaptive Situation Awareness Displays for Multi-UAV Supervisory Control
Effects of Automation

Automation is a double-edged sword

(+)
- Improvement of operational capabilities
- Reduction of cognitive and physical load
- Reduction of cost
- Reduction of human error

(-)
- Improper design
  - (Billings, 1997)
  - (Bainbridge, 1983)
- New sources of human error
  - (Jones & Endsley, 1996)
  - (Kaber & Endsley, 2004)
New Sources of Human Error

• Unlearning of manual skills and procedures
• Overtrust in automation
• Insufficient situation awareness
• Unbalanced workload
• ...
Situation Awareness
Definitions

Situation Awareness

“[...] knowing what is going on so you can figure out what to do.” (Adams, 1993)

“[...] what you need to know not to be surprised” (Jeannot & Thompson, 2003)

“[...] the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future.” (Endsley, 1995)
“[...] the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future.” (Endsley, 1995)
Situation Awareness Errors in the Control of Automated Systems

(Jones & Endsley, 1996)
Example 1

Unknown Driver, Oldenburg, Germany, 2010

Nordwest Zeitung – 23.09.2010
A regional newspaper in Oldenburg

Fahrer übersieht Rotlicht


!!!
Example 1

Unknown Driver, Oldenburg, Germany, 2010

What went wrong?
Level 1 error: Missperception
Example 2

Eastern Air Lines Flight 401, Miami, USA, 1972

1. Malfunction of the landing gear position indicator system
2. Go-around with autopilot engaged
3. Autopilot accidently disengaged by crew
4. ALT alert system triggers visual/auditory notification
5. Crash

What went wrong?
Level 1 error: Failure to monitor
Level 2 error: Overreliance on default values

http://www.ntsb.gov
“We know from many 'vigilance' studies that it is **impossible** for even a highly motivated human being to maintain effective visual attention towards a source of information on which **very little happens**, for more than about half an hour.” (Macworth, 1951)
Adaptive SA-Displays for Multi-UAV HSC
D3CoS Project


- Automotive
- Shipping
- Manned Aviation
- Unmanned Aviation
Unmanned Aerial Vehicles

- Unmanned Aerial Vehicles (UAV) are remotely piloted aerial vehicles
- Unmanned ≠ unpiloted
- Human operator is responsible
- Many UAV types for many use cases (military and civil)

Ramsauer: „Langfristig ist unbemannter kommerzieller Fracht- oder sogar Personenverkehr denkbar“ [Web1]
UAV Types

UAV-CR

MicroDrones MD4-1000
Weight: 2650g
Length: 1.03m
Width: 1.03m

Aladin
Weight: 4000g
Length: 1.53m
Width: 1.46m
UAV Types

UAV-SR

KZO
Weight: 168kg
Length: 2.26m
Width: 3.42m

P-15
Weight: 132kg
Length: 2.23m
Width: 3.34m
UAV Types

UAV-E

**EuroHawk**
- Weight: 6000kg – 13000kg
- Length: 14.53m
- Width: 39.42m
Multi-UAV Supervisory Control

(Insufficient) Situation Awareness

Human Operator

Situation Awareness Display

Unmanned Aerial Vehicles

Remote Control

HSC
Research Objective

Inadequate Monitoring Behaviour → Insufficient Situation Awareness → Human Errors → ...

RO: Develop an assistant to improve monitoring behaviour during supervisory control of many highly-automated UAVs
Adaptive Multi-UAV SA-Display

Dynamic adaptation of display characteristics to monitoring behavior

1. **Observation**
   - To observe the monitoring behavior

2. **Assessment**
   - To assess the adequacy of monitoring behavior

3. **Adaptation**
   - To adapt the characteristics of the display to adequacy of monitoring behavior

→ Eye Tracking

**RQ1:** How to assess adequacy of monitoring behavior during multi-UAV supervisory control?

**RQ2:** How to adapt displays used for multi-UAV supervisory control in order to improve adequacy of monitoring behavior?
Architecture

1. Observation

Eye Tracker

Fixations

Eye Movements

Human Operator

Interaction

2. Assessment

Monitoring Behavior Analysis Tool

Display State, Assessments

Adaptive SA-Display

3. Adaptation

Data

Multi-UAV Microworld

1. Observation
To observe the monitoring behaviour

2. Assessment
To assess the adequacy of monitoring behaviour

3. Adaptation
To adapt the characteristics of the display to adequacy of monitoring behaviour
Multi-UAV Displays

ENAC
Multi-UAV Displays

ENAC

Selex ES
Multi-UAV Displays
Map central element on multi-UAV displays
Firefighting mission

- UAVs used as firefighters
- Human operator monitors mission performance, detects & handles events

- Events
  - UAV malfunctions
  - Intruders
  - Collisions
Assessment of Monitoring Behavior Adequacy

Intruder

Fire Spot

Energy Supply

UAV

Water Supply

IE

IE

IE
Assessment of Monitoring Behavior Adequacy

Information Elements

- Intruder
- Energy Supply
- Water Supply
- Fire Spot

Attended-ness $A \in [0,1]$

Relevance $R \in [0,1]$

$\text{IE} \rightarrow A \rightarrow \text{IE}$

$\text{IE} \rightarrow R \rightarrow \text{IE}$
Assessment of Monitoring Behavior Adequacy

\[DfA_{IE} = R_{IE} \ast (1 - A_{IE}), \quad DFA \in [0,1]\]
Assessment of Monitoring Behavior Adequacy
Assessment of Monitoring Behavior Adequacy

Monitoring Behavior Adequacy (MBA) is high if average DFA-value of all IEs is low

Monitoring Behavior Adequacy (MBA) is low if average DFA-value of all IEs is high

\[ MBA = 1 - \left( \frac{1}{n} \sum_{i}^{n} DFA_{IE_i} \right), MBA \in [0,1] \]
Adaptation Concepts

Two adaptation concepts have been developed
Concept 1

Adaptive SA-display supports *visual search* for information demanding attention.
Concept 1

- Often operators really need different kinds of aid than technologists assume
  - Tell them what to do
  - **Tell them where to focus**
  
  vs
  
  - Integrate the information for them
  - Reduce repetitive tasks
  - Eliminate data entry
Concept 1: Design

No cues

Visual Cue Invocation Design 1

Visual Cue Invocation Design 2

DfA ∈ \{‘low’, ‘medium’, ‘high’\}
Concept 1: Design

Wedges
(Gustafson et al., 2008)

Halos
(Baudisch et al., 2003)
Concept 1: Evaluation

Evaluation of prototype with students in the lab of OFFIS in Oldenburg
Concept 1: Results

- Visual cue invocation is an appropriate method to drive monitoring behaviour
- Situation Awareness is significantly better
- Workload is significantly higher
Concept 2

Adaptive SA-display gives **visual feedback** about adequacy of monitoring behaviour
Concept 2

Continental: Driver Focus Technology [Web2]
Concept 2: Design

Neutral (White or Blue) | Color | Red | Blink

Low | Brightness | High

Adequate | Monitoring Behavior is... | Inadequate

05.12.2014    Florian Fortmann – Adaptive Situation Awareness Displays for Multi-UAV Supervisory Control
Concept 2: Evaluation

Evaluation of prototype with UAV Experts in the lab of Cassidian Airborne Solutions in Bremen
Concept 2: Results

- Feedback on monitoring performance with ambient light display (ALD) supports adequate performance of monitoring behavior
- Ambient visual cues do not distract from monitoring task
- Ambient visual cues do not increase workload

1. The ALD should support commanders to perform adequate monitoring behavior
2. The ALD should not distract commanders from the monitoring task
3. The ALD should not increase workload
4. The ALD should be compatible with a real UAV control station
Lessons Learned
Lessons Learned

Consider both parts when designing for automation

One part fits the problem/task

One part fits the human

Problem/task
References

Web Links

Selected Publications

