Kognitive Automation in der UAV Führung

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UAV Automation Perspectives

Driving Question
Future Trends in Supervisory Control

Theoretical Framework

Work System as Top-level Systems Engineering Approach
Artificial Cognition in the Work System

Applied Research Areas

Manned-unmanned Teaming
Operator Assistant Systems
UAV Automation Perspectives

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Automation is being introduced into vehicle control work processes in order to

• Maximise effectiveness
• Minimise risks
• Minimise costs
• Minimise manpower requirements

… but, how shall this Automation be introduced?

It is no question that automation will massively be introduced in UAV guidance …
Classical Flight Guidance System for Manned A/C

- Flight Management
- Autopilot
- FBW
- Damper
- Sensors
- Control & Display Unit
- Flight Control Unit
- Primary Flight Controls
- Electronic Flight Instrument System

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Airbus 320 Cockpit
Supervisory Control of a UAV

Flight Management → Autopilot → FBW → Sensors

Position → Altitude Speed Heading → Attitude

R/X → T/X

R/X → T/X

T/X → R/X

Control & Display Unit → Flight Control Unit

UAV

Ground Control Station

Electronic Flight Instrument System

Predator Control Station

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Human operator is the only instance pursuing the high-level work objectives. Automation functions have no idea of the overall situation and the goals of action. Automation:
- doesn’t explain its operation well
- quits service beyond rather narrow limits
- executes commands with slavish obedience

RESULT: Automation induced Human Error!

Classical Supervisory Control Paradigm pushes engineers towards a strong focus in just HMI design.

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Negative Effects of Automation

Demand on Operator Resources

Available Operator Resources

Positive Effect of Automation

Negative Effect of Automation

Clumsy Automation

Operator Workload

Demand on Operator Resources with conventional Automation

Demand on Operator Resources without Automation

Time

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Automation impact on safety

No further safety/efficiency increase possible despite automation advancements

Will the same thing happen with UAVs???

FAA (2004): “Predator UAV HF-related accidents 67%”
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The Work System as HF-Engineering Framework

**Human Factors**

- Purpose of work
  - Specified by other work system
  - Instruction, order or command

- Work site settings
- Non-powered tools
- Powered tools
  - Machines
  - Automation

**Work State**

- Env. conditions & supply
- Operating force
- Operation-supporting means

- Work product
  - Indicate degree of accomplishment of the work objective
  - Tangible accomplishment of work process

**Work Objective**

- High-end decision component
  - Pursues complete work objective
  - Supervises operation-supporting means
  - Can be human team

- e.g. information, resources

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Let’s assume:

1. A tremendous **progress in automation technology**
2. A massive **substitution of human capabilities by automation**

The **Two Good Reasons** for **not** building an **Autonomous System**:  
1. **Ethics:** We don’t want to take the risk … (cf. Isaac Asimov’s laws of robotics)  
2. **Pragmatism:** We don’t need technological artefacts not serving the human
What will happen as an alternative?
The Vicious Circle of Advancing Automation

The Aviation Psychologist’s magic moment
human fails in supervision of complex automation

The Aviation Engineer’s magic moment
human gets assistance from new fancy automation

The Aviation Engineer’s mistake
human has to supervise semi-autonomous automation system

The Human Factors Engineer’s magic moment
human transfers authority over comprehensive task to automation

The Aviation Engineer’s mistake
Escaping the Vicious Circle
Escaping the Vicious Circle

human and automation co-operate in close-partner work relationship

The Human Factors & Aviation Engineer's challenge
ACU: “Artificial Cognitive Unit”

“Semi-autonomous”
- Comprehensive sit. understanding
- Goal-directed task performance
- Rational decision-making
- Problem-solving & planning

“Assistant”
- Pursuit of overall work objective
- Understand human resources
- Goal-directed interaction
- Co-operation & co-ordination

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Assistant systems vs. other automation

**Semi-autonomous System**
- Needs to be *tasked by supervising authority*
- Is responsible for *well-defined task*
- Is able to perform that task with no or little human intervention
  => Is *Automation* (as part of the OSM)

**Assistant System**
- Pursues overall *work objective*
- *Co-operates* with other elements of the operating body
- Provides *situation-dependent intervention* (e.g. task adoption)
  => Is *Operating Element* (as part of the OB)

**Artificial Cognition**
- Might be a realisation approach for both
What capabilities does such an Assistant need?

Does the Assistant System necessarily need to mimic its human counterpart?

Does the Assistant System necessarily need to be as good as a human pilot?

NO !!!

The teamwork in an *operating room* is a much better paradigm:

- **chief surgeon** (= human operator) has *full operational capabilities*
- **surgical nurse** (= assistant “system”) has only very *limited scope* of understanding and action alternatives, but deploys these capabilities in accordance to the overall *work objective*
How shall this „Electronic Team Mate“ behave?

Basic Requirements for Human – Automation Co-operation

1st Basic Requirement

It *must be ensured* the representation of the *full picture of the situation*, including that the *attention of the human operator* is *guided towards* the objectively *most urgent task* as demanded in that situation.

- Automation needs to obtain situation awareness for itself first
- Automation needs to know high-level goals
- Automation needs to be interactive and communicate with the human operator

2nd Basic Requirement

A *situation with overcharge* of the human operator might come up even when situation awareness has been achieved. In this case the *automation has to transfer the situation into a normal one* which can be handled by the operator in a normal manner.

- Automation needs capability to recognise when human operator is overcharged
- Automation needs to feature co-operative behaviours of co-ordination & task allocation
- Automation needs capabilities to autonomously perform mission tasks
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Cognitive Process

Extensive simulator & flight tests

COSY

flight

COSY

team

machine teaming
capabilities

CAMA

Co²SiMA

UAV guidance & human-machine teaming

CASSY

simulator
tested

first prototype ever flown

PILAS

automated mission accomplishment

TIMMS

UAV guidance & human-machine teaming

MIRA

adaptive automation

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today

1990

2000
Manned-unmanned Teaming (MUM-T)

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MUM-T Work System Analysis: Hierarchy

Command & Control objective

flight mission objective

reconnaissance objective

CASSY – “Cockpit Assistant System”
CAMA – “Crew Assistant Military Aircraft”
TIMMS – “Tactical Information & Mission Management System”

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MUM-T Work System Analysis: loosely coupled Team

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MUM-T Work System Analysis: tightly coupled Team

Command & Control objective

flight mission objective

MUM-T – “Manned-unmanned Teaming / Remote Sensor Platform”
Adaptive Automation

(1) External events
- new mission order / contingencies / threats / hazards

(2) Observations & Measurements
- Task Performance (tracking accuracy / response times / errors)
- Psycho-physiological Measurements (EEG, eye movements)

(3) Models & Predictions
- Task Models (anticipation of objective work demands)
- Workload Models (estimation of subjective workload)
Cognitive & Co-operative System

Co²SiMA

for intelligent Mission Accomplishment

- Multiple UAV missions in surrogate scenario
- Operator assistance
- UAV guidance & control
- Machine-machine collaboration

mobile ground control station

ground control station design

H/C UAV

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Artificial Cognitive Unit (ACU)

- Semi-autonomous multiple UAV guidance
- Machine-machine collaboration
- Human supervisory control
- Effective agent communication

Tasks

Results

UAV Ground Operator

Basic Desire
Co-operation

Form a team
Know team members
Know resources
Know capabilities
Know commitments
Know opportunities

Support team members
Continue dialogue
Keep team members informed

Balance work
Do not overcharge team members
Involve all team members

Complete tasks
Ensure task coverage
Avoid redundant task completion

Achieve common objective
Comply with commitments

Achieve common objective
Comply with commitments

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**Summary**

**UAV Automation Perspectives**
We are expecting similar *automation induced problems* with UAV guidance as earlier observed in manned flight.

**Theoretical Framework**
The approach of the *Work System* allows a proper definition of future automation properties. *Artificial Cognition* helps implementation.

**Applied Research Areas**
We have considerable experience and confidence in *Assistant Systems*. Transfer of principles to *co-operative UAV Guidance* is on the agenda.