Towards an Ecological Design of a 4-Dimensional Separation Assistance Interface

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Department of Control & Simulation

Research:
• Dynamics and control
• Human-machine systems

Focus within human-machine systems:
Navigation, in future Air Traffic Management Concepts

June 18, 2008
The Predicted Future of Aviation

Forecast for 2026:
- World passenger traffic increase by 4.9% per annum
- IFR movements within Europe increase by 3% per annum
- Number of frequencies offered on routes more than double

Europe: Single European Sky ATM Research
- User preferred routing
- Managed vs. unmanaged airspace

The Concept of Self-Separation

Human is main separator, not Air Traffic Control

Assisted by:
- Airborne Collision Avoidance System (ACAS)
- Airborne Separation Assurance Systems (ASAS)

Predictive-ASAS:
- Explicit conflict resolutions
- Low Traffic Awareness
Human Supervisory Control and Ecological Interface Design

Human Supervisory Control

- Human control task is highly automated, human role shifts from controller to supervisor of the automated system
- Human relies on feedback and resolutions provided by automation

Danger appears in case of unanticipated events:

- Human needs Traffic Awareness for resolutions
- Human needs indication of urgency
- Human needs understanding of consequences of resolutions

Content

- Introduction
- The EID design paradigm
- The actual design
- Conclusions
- Future Research
Ecological Interface Design

- Human actions are constrained by the environment or work domain, so the work domain must be understood before starting a design.

- It is possible to design interfaces that provide information that the human can pick up and use.

- There are visual ways of displaying information that can reduce the need for memory or mental calculation.

Skill, Rules, Knowledge Behavior

[Diagram showing the interrelations between skill, rules, knowledge, and behavior]
Approach in EID

- Work domain analysis
  - Cognitive and environmental constraints
  - Abstraction Hierarchy

- Visualize the workspace constraints

Previous Research within C&S

Available Displays in the cockpit:
- Navigation Display: Speed and Heading
- Primary Flight Display: Climb/Descent and Heading
- Vertical Situation Display: Climb/Descent and Speed

Horizontal plane
- (Extended) Airborne Trajectory Planning

Vertical plane
- Vertical Separation Assistance Display
Previous Research within C&S

The Abstraction Hierarchy

<table>
<thead>
<tr>
<th>Functional Purpose</th>
<th>Internal</th>
<th>External</th>
</tr>
</thead>
<tbody>
<tr>
<td>What is the primary goal of the system?</td>
<td>Productivity</td>
<td>Principles of absolute and relative motion</td>
</tr>
<tr>
<td>Abstract Function</td>
<td>Efficiency</td>
<td></td>
</tr>
<tr>
<td>What are the key aspects of the system?</td>
<td>Comfort</td>
<td>Weight, Lift, Maneuvering, Obstruction</td>
</tr>
<tr>
<td>Generalized Function</td>
<td>Energy, Equations</td>
<td></td>
</tr>
<tr>
<td>What are the fundamental principles of the system?</td>
<td>Safety</td>
<td>Threat and Drop, Manoeuvering</td>
</tr>
<tr>
<td>Physical Function</td>
<td>Structure, Mechanisms, Avionics, Traffic</td>
<td></td>
</tr>
<tr>
<td>What is the physical apparatus of the system?</td>
<td>Location and Appearance of ownership components, Appearance, Location and Appearance of Traffic</td>
<td></td>
</tr>
</tbody>
</table>
The Information Requirements

<table>
<thead>
<tr>
<th>Abstraction Level</th>
<th>Information Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Functional Purpose</td>
<td>Information of the destination (spatial coordinates and time)</td>
</tr>
<tr>
<td></td>
<td>Information of the user-preferred trajectory</td>
</tr>
<tr>
<td></td>
<td>Information on the (conflict) situation with intruder(s)</td>
</tr>
<tr>
<td></td>
<td>Information of (efficiency of resolution) possibilities</td>
</tr>
<tr>
<td>Abstract Function</td>
<td>Information of the energy balance</td>
</tr>
<tr>
<td></td>
<td>Information on the (loco-) motion of the intruder(s)</td>
</tr>
<tr>
<td>Generalized Function</td>
<td>Information on the performance characteristics</td>
</tr>
<tr>
<td></td>
<td>Information on the ownership configuration</td>
</tr>
<tr>
<td></td>
<td>Information on the ownership kinematics</td>
</tr>
<tr>
<td>Physical Function</td>
<td>Information of the intruder(s) characteristics</td>
</tr>
<tr>
<td></td>
<td>Information of the structure</td>
</tr>
<tr>
<td></td>
<td>Information of the mechanisms</td>
</tr>
<tr>
<td>Physical Form</td>
<td>Information of the avionics</td>
</tr>
<tr>
<td></td>
<td>Information of the traffic</td>
</tr>
<tr>
<td></td>
<td>Information of ownership state variables</td>
</tr>
<tr>
<td></td>
<td>Information on intruder(s) state variables</td>
</tr>
<tr>
<td></td>
<td>Information on intruder(s) control variables</td>
</tr>
<tr>
<td></td>
<td>Information of the surrounding airspace</td>
</tr>
</tbody>
</table>

Relative Speed and Protected Zone

\[ R = 5N/\text{m} \]

\[ PZ_{\text{room}} \]

\[ PZ_{\text{intruder}} \]
Relative Intruder Motion

The Danger Area Protected Zone
A Horizontal Situation Visualization

The Vertical Situation
The Resulting Visualization

The 4-Dimensional Self-Separation Assistance Interface
Future Research

- Implement rest of requirements
- Research required resolution behavior
- Experiment with human in the loop
  - Investigate Traffic Awareness pilot
  - Investigate the Functional Purpose of the system

References


