Tactical inputs for a stripless ATC system via Multi-Touch Gestures

Dr. Konrad Hagemann & Andreas Udovic

Introduction

"The DFS research centre is no ivory tower and doesn’t want to be one. … It is not about looking in the far future. The things that the colleagues are working on could already be implemented within the next 10 years." (cited after Ciupka, 2019). In accordance with this mission statement, DFS research centre focusses its research and development (R&D) efforts on technologies that are presumably mature enough to be deployed "on board" and to facilitate the ATCOs’ work in the future.

There are big challenges that DFS will address within the next 10 years. One of them is the change to the stripless ATC system iCAS (iTEC Center Automation Systems) for lower airspace in German ATC centres, which will introduce new working procedures for the controllers. As part of its mission, the DFS research centre is investing significant effort in co-operations and programs on national and international level to develop concepts for future Air Traffic Control. In 2018, grant funding payments of €12.7 million were received for whole DFS from European research framework programmes, including SESAR and the German aeronautical research programme (DFS, 2019a, p. 20).

The Single European Sky ATM Research program (SESAR) is currently one of the most prominent Air Traffic Management (ATM) R&D initiatives worldwide (Tauss, 2017). The aim of SESAR 2020 project 16 is to reduce development and operating costs of Air Navigation Service Providers (ANSP). It achieves this by delivering the ATM Master Plan goals (defined by the European ATM community) for a more efficient deployment of human resources, a progressive increase in automation support, the implementation of virtualisation technologies and the use of standardised and interoperable systems whilst increasing the safety level. The PJ.16-04 "workstation, controller productivity" solutions deal with new methods of controller interaction with the Human Machine Interface (HMI), applying mature technologies from other domains to ATM. This will increase controller productivity, reduce workload, stress level and enable the use of SESAR advanced tools, safely facilitating performance based operations. One of these methods includes the use of Multi-Touch Inputs (MTI) at the controller working position (CWP, cf. SESAR, 2019a).

Background

Today, multi-touch technology is considered a mature technology, which is in everyday use in various environments (cf. SESAR, 2018). For example, tablets and smartphones are operated by multi-touch input and a standard set of gestures are known by most of the users (e.g. pinch to zoom). Products with multi-touch gesture interaction are often advertised with a promise to be faster, more direct and intuitive for the user. Nowadays, interaction via mouse, pen (paperless strip system, PSS) or single touch (voice communication system, SVS) are used for interaction with the ATC system at DFS (see also Hagemann & Udovic, 2014). So far, it has only been since the last couple of years that DFS put focus on the use of (multi-touch) gestures in the context of research and development activities. Several approaches have been taken to evaluate and pin-down the assumed benefits for ATCOs:

- In 2012, an early concept following a playful, multimodal approach has been realized as part of a student work (Wald, Buxbaum & Konopka, 2012).
- As part of a technology screening in SESAR 1, a direct and an indirect interaction concept involving different sets of multi-touch gestures have been researched (Hagemann & Udovic, 2014).
- Over a series of three validations DFS investigated an in-house built iCAS multi-touch Touch Input Display (TID) prototype that was capable of replacing the mouse completely (2-TID, cf. Schibl, Perott & Schader, 2013a, 2013b, 2014).
- In 2015, DFS ordered a platform for the design of potential future ATCo workstations. The design-awarded Concept Desk can be operated with Multi-Touch gestures and in its first version even included the capability to process tangibles objects (Buxbaum, 2015).

Most recently, with SESAR solution 16-04 DFS developed a demonstration concept to integrate multi-touch gesture operations for frequent tactical inputs into a stripless system. The focus of this development was to:

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http://www.dfs.de/dfs_homepage/de/Flugsicherung/Forschung%20&%20Entwicklung/Servicebereich/Forschungszeitschrift%20E2%80%9EI innovation%20im%20Fokus%20E2%80%9C/
a. Demonstrate a multi-touch gesture interaction concept that may ease handling frequently required system inputs and that is ready for use

b. Demonstrate together with INDRA its technical feasibility on the INDRA Industry-Based Platform (IBP).

### Multi-Touch Interaction Concept

The Multi-Touch interaction concept has been developed over a series of six concept workshops together with ATCOs from different DFS ATC centres, software specialists and human factors experts as well as design experts from the University of Applied Sciences in Osnabrück. The interaction concept focussed on defining an intuitive and efficient solution for frequent tactical system inputs. Figure 1 illustrates the core elements of the concept by showing a typical workflow of selecting a label, opening a menu, selecting values and confirming it.

#### Table 1: Complete set of gestures.

<table>
<thead>
<tr>
<th>Gesture Type</th>
<th>Gesture</th>
<th>Gesture</th>
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<tbody>
<tr>
<td>Single Tap</td>
<td>Select label</td>
<td>Open menu</td>
<td>Confirm</td>
<td>Feedback</td>
<td>Close</td>
</tr>
<tr>
<td>Double Tap</td>
<td>Change label</td>
<td>Open menu</td>
<td>Confirm</td>
<td>Feedback</td>
<td>Close</td>
</tr>
<tr>
<td>Finger/Finger</td>
<td>Move menu on screen</td>
<td>Select value</td>
<td>Confirm</td>
<td>Feedback</td>
<td>Close</td>
</tr>
<tr>
<td>Finger/Finger</td>
<td>After opening label menu for entry or displayed select a value in menu</td>
<td>Select value</td>
<td>Confirm</td>
<td>Feedback</td>
<td>Close</td>
</tr>
<tr>
<td>Finger/Finger</td>
<td>Select label</td>
<td>Move label to position</td>
<td>Feedback</td>
<td>Feedback</td>
<td>Close</td>
</tr>
<tr>
<td>Finger/Finger</td>
<td>Move menu on screen</td>
<td>Label select move label</td>
<td>Feedback</td>
<td>Feedback</td>
<td>Close</td>
</tr>
<tr>
<td>Finger/Finger</td>
<td>After opening label menu for entry or displayed select a value in menu</td>
<td>Select value</td>
<td>Confirm</td>
<td>Feedback</td>
<td>Close</td>
</tr>
</tbody>
</table>

All multi-touch inputs could be done within a dedicated multi-touch area on the TID while the menus were shown on the radar display. To ease the learning of the gestures a help window could be manually triggered for display at the left side of the radar display. In addition, some more complex inputs (e.g. combined clearances) were available and can displayed on the TID. However, they were rarely used in the technical demonstration as they would have required the ATCOs to look down from their radar screen.

The TID user interface was based on previous DFS prototype developments (Schilb, Perott & Schader, 2013a, 2013b, 2014) and has been updated to account for recent design guidelines. Overall, the complete layout of the menus in the mock-up and demonstrator was based on the “Styleguide for iCAS TID” developed by DFS (Tenoort & Hagemann, 2017).

### Aim of the Demonstration

In sum, the following benefits were expected to be supported by the feedback collected during the demonstration:

The use of multi-touch gestures should...

- ...provide fast and efficient input for most frequent tactical inputs, i.e. clearances
- ...show high user acceptance through usability and attractiveness of the man-machine interface
- ...minimize head down time when using the TID for touch inputs together with the air situation window (ASW) for information display

The scope was to run a technical demonstration instead of a full-scale validation. Therefore, not all parts of the concept were implemented. Following this, a special challenge lied in realizing a show-case solution involving both a sufficiently complete concept mock-up and a running industrial prototype. In the end and due to
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Constraints in development time, the latter could only show parts of the concept in operation on the IBP.

Methods

Participants

Thirty-one participants (4 female, 27 male) took part in the technical demonstration. The average age of the participants was 42 years with a job experience of 13.5 years. 17 ATCOs (11 Centre controllers, five approach controllers and one tower controller), six HMI experts and two software developers participated in the demonstration. In addition, eight other DFS employees took part in the event. The participants reported to have a very heterogeneous level of experience with using multi-touch. Five participants answered that they were not confident with using multi-touch gestures at all (overall mean = 3.29, SD = 1.76, see Figure 4, question 1)

Technical Set-Up

Two stations with prototypes representing different development steps (stand-alone concept vs. industry-based platform demonstrator) of almost completely the same user interface design concept (i.e. with a similar set of gestures) were used for the technical demonstration.

For station 2 (see Figure 3), ATM system manufacturer INDRA had transferred the interaction concept on the SESAR IBP (iCAS System) together with a simulation capability, i.e. the input into the menus of the demonstrator were sent to the Flight Data Processing System (FDPS) so that a real behaviour of the system was realised. This demonstrates a basic technical feasibility of the developed solution in a real-life ATM System. At this station, the touch-monitor hardware was identical to the one that has been previously selected for the implementation of iCAS phase 2 at DFS.

The mock-up and the demonstrator were different in certain details: for example, the demonstrator did not provide an input via heading menu, instead only a picture was displayed. On the other hand, the demonstrator allowed the user to scroll up and down inside some of the ASW menus (e.g. flight level and speed menu), which was not implemented in the mock-up.

Schedule

Altogether ten demo slots of 1.5 h duration were run over five days.
Table 2 shows the schedule of one slot of the Technical Demonstration. It was designed such that participants were split-up in two groups who were testing the two prototypes in parallel. The briefing at the beginning and the debriefing at the end were done with the whole group. At the station, participants were encouraged to continuously speak out loud their impressions while observers took notes.

**Results**

**Results from the questionnaire**

Figure 4 to Figure 5 show the result of the questionnaire filled in by the participants. One central hypothesis for the demonstration was that the input via gestures is faster than by mouse and/or keyboard. The colleagues did not support this assumption. The average of the answers related to this question was 3.34 (see question 5, in Figure 4). The participants rated the input speed to be slower than with mouse. Compared with the actual used Paperless Strip System (PSS), which is operated by a pen, the difference in speed is estimated even greater. Again, the speed was rated lower for input via gestures than for using the pen (average 3.91, see question 6 in Figure 4). In total, the input speed via gesture was rated with 2.97 in average as medium fast. Many of the participants with professional background as an ATCo are very well trained with using the pen for system input in their job. It is expected that with more training for the novel input modality the estimated input speed for multi-touch gestures will improve. Clearly, for a valid comparison of the different interaction modes a large scale validation exercise would be necessary.

Besides this, the overall concept was rated as suitable for handling an ATC system (average 2.31, question 2 in Figure 4).

Safety was another topic, which should be investigated in the demonstration. Therefore, two questions were asked to the participants. The first question addressed the error tolerance and the second question was related to the possibility to correct wrong inputs. The failure tolerance of the system was rated negatively by trend (mean = 3.70). The question related to the possibility to correct false input was estimated slightly more positive. A mean of 2.91 indicates that this point should be improved.

Another hypothesis for the demonstration was the assumption of a high usability of the gestures and menus. Figure 5 and Figure 6 show results related to this hypothesis. The participants rated all gestures and menus as suitable. Only the selection of the flight level in the flight level menu (question 11, see Figure 5) was rated in tendency more negative (mean = 2.97).
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Results from the verbal feedback during the demonstration and debriefing

All participants had the possibility to use the INDRA demonstrator and the DFS mock-up. Altogether, the participants provided many comments during the demonstration. During the interaction with the systems, the participants were encouraged to think aloud and give recommendations or ask questions. Colleagues from INDRA and DFS collected this feedback. At the end of the demonstration all participants have had the possibility to summarize their impressions in a debriefing. To structure the debriefing some questions were prepared to guide the discussion.

Overall, the participants were in favour of the concept. Also the presented HMIs (e.g. menus) were judged positive by the majority. The discussions revealed some additional ideas for specific aspects (e.g. scaling of heading menu, switch of gestures for certain functions, add another abort function in menus). The ideas were recorded for potential testing in future versions of the prototype. Furthermore ergonomic issues were commented like position of hand, strain by prolonged periods of interaction, haptic quality of the TID and hygienic. These aspects may need to be considered in more detail in the future.

Discussion

In summary, the multi-touch solutions developed by INDRA and DFS were successfully presented during the demonstration. Although at the beginning, the participants reported to have a very heterogeneous level of confidence with the use of multi-touch gesture input in general, the concept was rated as useful and shall be further investigated, e.g. in real-time simulations. This may speak for the intuitiveness of the approach. Nevertheless, details of the concept and HMI can be optimized and improved (e.g. assignment of gestures to functions, heading inputs, touch screen surface). The participants gave a lot of comments and recommendations in this direction. The assumption that the inputs by multi-touch are faster than by mouse or pen was not supported by the participants. Therefore, the participants expressed their wish to test the multi-touch input concept in a validation exercise with long validation runs (two hours), including training and reference runs. In addition, possible effects of strain on the fingers and wrist can then be investigated. The failure tolerance of the concept was also criticized and has to be improved. A point that should also be investigated during a validation trial.

Outlook

Based on the collected data from three validation exercises plus one technical demonstration, the SESAR 2020 project partners, including leading European ATM industry, came to the conclusion that no more pre-deployment research is needed to implement multi-touch gestures at the CWP (SESAR, submitted). The technology itself is considered mature. Among others, DFS and INDRA successfully demonstrated the technical feasibility of a working multi-touch interaction concept on an industry-based prototype. As a consequence, within the SESAR project it is currently under discussion with the SJU to proceed directly from Technical Readiness Level (TRL) 4 for this solution, towards TRL 6 (i.e. “ready for deployment”) by end of SESAR wave 1 in 2019.

On the other hand, for DFS that started R&D work on the topic in 2012, an implementation within a 10-year limit (see above Ciupka, 2019) is currently not in view. For the iCAS deployment within the next years, DFS focusses on using the mouse for tactical inputs and using single touch on the TID for strategic inputs. Although a technical feasibility could be demonstrated, jumping directly to deployment may still hold a high risk at the moment. From DFS point of view, the concept needs further validation in a highly realistic environment such as a full-scale real-time simulation including sufficient training and reference runs. As the technical demonstration has shown, the introduced multi-touch interaction concept for tactical inputs still holds some significant open gaps that could not yet be addressed and open questions such as physical strain over time can only be satisfactorily answered in real-time simulations.
More research and discussion about feasible innovation at the workstation is needed. Therefore, a permanent installation of the SESAR DFS demonstrator has been realized in the Advanced Function Simulator room of the DFS research centre in Langen. It is used to continue the discourse and to inform about the status of the research results at the end of SESAR 2020 wave 1 (e.g. for DFS future systems class). As an additional part of DFS dissemination activities, the demonstration concept has also been successfully transferred to another demonstration platform (2nd generation of concept desk, see Figure 7 and Buxbaum, 2015), which allows its presentation to a wider audience on events and to further discuss merits and flaws of the approach.

In the discussions about multi-touch gesture input a potential combination with Automatic Speech Recognition (ASR), has frequently been brought up in the debriefings. For example, voice input could help to automatically select targets on the radar screen, which would be quicker than using touch input and maybe even the mouse to move a cursor. Most recently, DFS ASR results on a target location assistance have shown a high reliability for the recognition of call signs spoken by the ATCo (SESAR, 2019b). To explore benefits of using multimodality in ATC, various studies have tried to shed more light on the discussion (e.g. TriControl Concept, Ohneiser, Jauer, Gürlük & Uebbing-Rumke, 2016; Eurocontrol, 2007). Research in this area should be continued to get a better understanding and quantify the possible benefits and limitations for the ATCos. A claim that is supported by the European ATM Master Plan, which explicitly lists R&D activities to see “the development of new human machine interface (HMI) interaction modes in relation to other SESAR Solutions (including new user interface technologies, such as speech recognition, multi-touch and gaze detection)” (SESAR, 2015, p.52).

In sum, much potential lies in the further optimization of the ATCo workplace and in the provision of a modern human-machine interaction concept for ATC systems that may meet the high expectations of current and upcoming controller generations. A challenge that the DFS research centre intends to address in more depth in future R&D activities and projects.

**Abbreviations**

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>ANSP</td>
<td>Air Navigation Service Providers</td>
</tr>
<tr>
<td>ASR</td>
<td>Automatic Speech Recognition</td>
</tr>
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<td>ASW</td>
<td>Air Situation Window</td>
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<tr>
<td>ATCo</td>
<td>Air Traffic Controller</td>
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<tr>
<td>ATM</td>
<td>Air Traffic Management</td>
</tr>
<tr>
<td>ATS</td>
<td>Air Traffic Services</td>
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<tr>
<td>CWP</td>
<td>Controller Working Position</td>
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<td>FDPS</td>
<td>Flight Data Processing System</td>
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<tr>
<td>HMI</td>
<td>Human Machine Interface</td>
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<tr>
<td>IBP</td>
<td>Industrial Based Platform</td>
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<tr>
<td>iCAS</td>
<td>iTEC Center Automation Systems</td>
</tr>
<tr>
<td>MTI</td>
<td>Multi-Touch Inputs</td>
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<tr>
<td>PSS</td>
<td>Paperless Strip System</td>
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<tr>
<td>R&amp;D</td>
<td>Research and Development</td>
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<tr>
<td>SESAR</td>
<td>Single European Sky ATM Research program</td>
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<tr>
<td>SVS</td>
<td>Sprachvermittlungsystem</td>
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<tr>
<td>TID</td>
<td>Touch Input Display</td>
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**References**

• EUROCONTROL (2007). Multimodal interfaces: a brief literature review. EEC Note No. 01/07.

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