Introduction of a Language Technology System as a Support for Air Traffic Control Communication

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Abstract: - Voice communication is one of the most essential parts of the Air Traffic Control. Investigations of several major airline accidents over the last few decades have found that lack of language proficiency by pilots and controllers has been a major causal factor. According to research, on average one miscommunication happens every hour per radio frequency. Therefore, it is important to emphasise that communication plays an integral function in air traffic, especially from the perspective of aviation safety. The International Civil Aviation Organization (ICAO) puts great emphasis on improving communication in Air Traffic Control and gives guidelines for setting language requirements for pilots and controllers in the Document 9835.

This paper proposes the idea that with the usage of language technology the communication between air traffic controllers and pilots could be made more reliable and efficient, and in that way would contribute to the improvement of aviation safety. The functionality of this language system will be described using scenarios and sequence diagrams, using Approach Control as an example, and will be demonstrated using the Wizard of Oz usability test. The results will serve as guidelines for designing a fully functional language technology system. The proposed system would only be designed as a support tool by giving warnings when discrepancy or error is found. The system is not meant to make decisions how the air traffic controllers should control the airspace.

Key-Words: - air traffic control, air traffic control communication, language technology, automatic speech recognition, speech to text technology, radiotelephony language corpus, error correction

1 Introduction

The role of the Air Traffic Control is to ensure safe, orderly and expeditious flow of traffic. One of the most crucial tasks that Air Traffic Controllers, pilots and anyone who takes part in aviation perform is communication. Communication can be defined as an exchange of information, ideas and knowledge. The traditional model of communication consists of a sender, a channel and a receiver. Figure 1 illustrates this model emphasizing spoken verbal (oral) communication, which is the form of communication that is addressed by the ICAO language proficiency requirements. The speaker and hearer participate in a given phase of communication. The speaker encodes his or her intended meaning in a spoken utterance. The utterance is conveyed via the appropriate channel in the form of a sound-stream which is perceived and decoded by the hearer. The hearer’s representation of the meaning of the utterance will, in the case of successful communication, be a perfect or near-perfect match of the speaker’s intended meaning.

Fig. 1, Traditional model of communication.
When we talk about communication in ATC system, a bit different definition of communication should be taken into account. In Air Traffic Control it is of vital importance that all parties involved in communication understand each other and that the information is delivered and received timely and accurately. The deadliest accident in aviation history, the Tenerife airport disaster in 1977, was a collision involving two Boeing 747 passenger aircraft with 583 fatalities. It was a defining event in aviation safety and a tragic lesson in communication. This accident demonstrated that information transmitted by radio communication can be understood in a different way to that intended. Ambiguous terminology and/or the obliteration of key words or phrases, and that the oral transmission of essential information, via single and vulnerable radio contacts, carries with it great potential dangers. The major part of communication in Air Traffic Control is voice communication over the radio. Due to many factors such as homonyms, number problems, readback/hearback error, call sign confusion, ambiguity, expectation, noise, open microphones, etc. errors in communication may occur. This paper proposes that language technology can be used to assist in Air Traffic communication and thereby would contribute to the improvement of aviation safety. It also tries to identify opportunities for its improvement and its application within Air Traffic Control Services.

2 The Structure of Air Traffic Control

According to EUROCONTROL, the European Organisation for the Safety of Air Navigation, Air Traffic Controllers have the responsibility to direct aircraft through their airspace safely and efficiently. The pilots flying the aircraft through the airspace are obliged to follow the instructions of the Air Traffic Controllers precisely since there is no leeway for discrepancy in today's overly crowded airspaces. The purpose of the communication is to synchronize the Air Traffic Controller’s decisions with the pilot and aircraft doings. This makes communication a vital part of the Air Traffic Controllers’ and pilots’ job.

A flight is divided into certain phases: pre-flight, take-off, departure, en-route, descend, approach, and landing (Figure1). These phases are defined by what the plane does in certain stage of flight. Each of the phases is handled by a different controller.

Fig. 2, Phases of flight [6].

The prime objective of Air Traffic Services as defined in Annex 11 to the Convention on International Civil Aviation is to prevent collisions between aircraft, whether taxiing on the manoeuvring area of an aerodrome, taking off, landing, flying en-route, or flying in the holding pattern at an aerodrome. Division of Air Traffic Control Services is shown in figure 3.

Fig. 3, Division of Air Traffic Control Services.

As an aircraft travels through a given airspace division, it is monitored by the one or more air traffic controllers responsible for that division. The controllers monitor this plane and give instructions to the pilot. As the plane leaves that airspace division and enters another, the air traffic controller passes it off to the controllers responsible for the new airspace division.

3 Communication architecture in Air Traffic Control
According to a survey carried out by the NASA Aviation Safety Reporting System (ASRS), incorrect or incomplete pilot / controller communications is a causal or circumstantial factor in 80% of incidents or accidents, as illustrated in Table 1. The following factors affecting pilot/controller communication have been identified:

<table>
<thead>
<tr>
<th>Factor</th>
<th>Percentage of Reports</th>
</tr>
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<tbody>
<tr>
<td>Incorrect Communication</td>
<td>80%</td>
</tr>
<tr>
<td>Absence of Communication</td>
<td>33%</td>
</tr>
<tr>
<td>Correct but late</td>
<td>12%</td>
</tr>
</tbody>
</table>

The environment in which pilot/controller communication takes place is a time-sensitive environment. Pilots and controllers cannot see each other or each other actions, so an important means of error detection is unavailable.

4 Radiotelephony Phraseology

As miscommunication can, and does, occur not only between non-native speakers but also between native speakers of the same language the International Civil Aviation Organisation has introduced a set of prescribed rules governing aeronautical communication. The rules for this language are located in Annex 10, Volume II, and Chapter 12 of Doc 4444. These are the basis of a “restricted” sub-language for routine situations. They contain rules for when to say something, what to say (words and sentence patterns), what to understand and how to pronounce and utter messages/instructions. The use of phraseology is further illustrated in Doc 9432.

The standardized Phraseology is intended to be employed by all those involved in aeronautical radiotelephony communications. Phraseology has the specific technical function of ensuring efficient and safe communications. The principal linguistic characteristics of standardized Phraseology (Philps, 1991) are a reduced vocabulary (around 400 words) in which each word has a precise meaning, often exclusive to the aviation domain. Sentences are short resulting from the deletion of “function words” such as determiners (the, your, etc.), auxiliary and link verbs (is/are), subject pronouns (I, you, we) and many prepositions. Sentences also frequently contain nominalizations (verbs transformed into nouns). A high proportion of sentences (around 50 per cent) are imperative or passive. Examples of such sentences are:

- Cleared to take off.
- Ready for push back.
- Confirm brakes released.
- Requesting low pass.

It is also important to acknowledge that Radiotelephony Phraseology represents a set of operational procedures. However, compliance with ICAO standardized Phraseology is not fully harmonized on a worldwide basis. States publish differences with respect to ICAO Standards. Croatia Control Ltd., Aeronautical Information Service, issues Radio Communication Procedures (Voice Communication in Aeronautical Mobile Service) in a document called AIC. The Croatian RT Phraseology, technique, and procedures are based on ICAO SARPS (Standards and Recommended Practices). Pilots should always read back the ATS messages/instructions detailed in AIC. Controllers should always ensure that they receive these readbacks. The ATS items listed below are to be read back in full by the pilot. The mandatory items are:

- Taxi/Towing Instructions
- Level Instructions
- Heading Instructions
- Speed Instructions
- Airways or Route Clearances
- Approach Clearances
- Runway-in-Use
- Clearance to Enter, Land On, Take-Off On, Backtrack, Cross, or Hold Short of any Active Runway
- Secondary Surveillance Radar Operating Instructions
- Altimeter Settings
- VHF Information
- Frequency Changes
- Type of ATS Service
- Transition Levels

If a readback is not received, the pilot will be asked to do so. Similarly, the pilot is expected to request that messages/instructions are repeated or clarified if they are not fully understood.

The language of pilot/controller communication is intended to overcome the basic shortcomings. The first priority of any communication is to establish “an operational context” that defines the following elements:

- Purpose – clearance, instruction, conditional statement or proposal, question or request, confirmation;
- When – immediately, anticipate, expect;
- What and how – altitude (climb, descend, maintain), heading (left, right), airspeed;
- Where – (at [...] waypoint).

The construction of the initial message/instruction and subsequent message(s)/instruction(s) should support this operational context by:

- Following the chronological order of actions;
- Grouping instructions and numbers related to each action;
- Limiting the number of instructions in the transmission.

Standard Phraseology helps lessen the ambiguities of spoken language and facilitates a common understanding among speakers. Nonstandard Phraseology, usage of plain English or the omission of key words may change completely the meaning of the intended message/instruction, resulting in potential traffic conflicts.

5 Miscommunication

Miscommunications may broadly be applied to a range of verbal communications problems ranging from misunderstandings, such as those due to ambiguity, cultural differences, language structure, and so on, to more technical problems, such as microphone “clipping” and over-transmitting of another’s radio signal. Studies indicate that miscommunication is a pervasive problem in air traffic control and, has been a causal factor in numerous fatal accidents.

According to the previous researches types of miscommunication can be grouped as follows:

1. Absent-mindedness and Slips
2. Ambiguity
3. Callsign Confusion
4. Code Switching
5. Different Voices
6. Emergencies
7. Enunciation
8. Expectation
9. Headsets
10. Homonyms and Homophony
11. Noise
12. Not Hearing
13. Number Problems
14. Open microphones
15. Readback Error
16. Similarity of SIDs (Standard Instrument Departures), STARs (Standard Recommendations and Practices) and Waypoints
17. Speech Acts
18. Speed of Delivery and Pauses
19. Vigilance.
6 Proposed Language Technology System

This paper proposes the idea that with the usage of language technology the communication between air traffic controllers and pilots could be made more reliable and efficient, and in that way would contribute to the improvement of aviation safety. Here, in this paper, it is also suggested that the usage of a language technology system could support the pilot/controller communication and assist with training. The system should assist in:

- detecting language-based communication problems such as unfamiliar RT terminology, full and partial readback/hearback errors;
- communication problems not based on language such as problems with numbers, discrepancies between position reports and clearances (altitude, heading, etc.);

The system should be applied in the Approach Control Unit, as according to the interview with air traffic controllers and the instructors of RT Communications at the Faculty of Traffic and Transport Sciences in Zagreb, the majority of prescribed standard RT communication is used in that phase of flight.

The functionality of this language system will be described using scenarios and sequence diagrams, using Approach Control as an example, and will be demonstrated using the Wizard of Oz usability test.

Scenarios are a software definition method. They are stories that provide a common ground for understanding the functionality of a system and give a context of a plot with participants and events that lead towards a certain goal or objective. Furthermore, sequence diagrams will be used to depict which parts of the system are interacting to carry out functionalities and to remove all ambiguity and clearly define the behaviour of the system. Additionally, the Wizard of Oz usability test will provide the same scenarios in that the images of the software prototype will be presented to the users by a “wizard” (the experimenter) behind the scenes. The user believes that a fully functional application system is used. The objective of such usability testing is to get information on how the user reacts to the system and how accurately and reliably the system reacts to the user.

The results will serve as guidelines for designing a fully functional language technology system. The fully functional language technology system should consist of an Automatic Speech Recognition tool that should identify the words that a user utters into a microphone or telephone. A Speech-to-Text software should convert the utterances into a text. The uttered/written text will be compared with the database consisting of RT Phraseology, prescribed RT instructions and related numbers. Finally, the system should report on discrepancies or errors. The proposed system would only be designed as a support tool by giving warnings when discrepancy or error is found and is not meant to make decisions how the air traffic controllers should control the airspace.

7 Conclusion

The proposed language technology system should detect deviation from the prescribed usage of radiotelephony phraseology by detected at least 80% of the types of miscommunication regarding language-based communication problems and problems with numbers (discrepancies between position reports and clearances). By making the controller and pilot aware of deviations from protocol, such as a failure to give readback or failure to use correct wording, the system may strengthen lax communication and help avoid operational mistakes. This system could prove useful not only when implemented in communication between controllers and pilots but also during pilot training.

References:


