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INTELLIGENT COMMUNICATION SYSTEM BASED ON AUTOMATIC SPEECH RECOGNITION - COMPILING CORPUS OF PHRASEOLOGY

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Abstract- The proficiency in Aeronautical phraseology and the ability to produce intelligible messages in abnormal and emergency situations must reach an agreed minimum level, as communication errors and misunderstandings in such situations can have tragic consequences. The aim of this paper is to present an overview of the specialized corpus of aeronautical phraseology for future use in speech recognition applications. The language corpus has been compiled and will be used as a basis for the design of the Intelligent Communication System, which should recognize phraseology errors made by air traffic controllers when managing emergency and abnormal situations. Air traffic controllers are trained to use the standard phraseology of the International Civil Aviation Organisation (ICAO). However, with stress and lack of practice, this phraseology can be altered without the air traffic controller being aware of it. The recordings were made in an Air Traffic Control (ATC) simulator environment at the Mohammed VI International Civil Aviation Academy (AIAC), and subsequently transcribed and incorporated into the Intelligent Communication System. Although the corpus designed is restricted, it already provides us with material to study the oral interactions of air traffic controllers in abnormal and emergency situations.

Keywords: Air Traffic Control Communication, Spoken Corpus of Phraseology, Automatic Speech Recognition, Intelligent Communication System, Emergency Services.

1. INTRODUCTION

Given the high reliability of modern aviation systems, human performance has become a key element of flight safety [1]. Maintaining and improving human performance can only be achieved by focusing training on the skills needed to perform tasks safely and effectively, and if training involves a variety of scenarios that expose people to the most relevant threats and errors in their environment [2], [3]. Different academic studies in the field of natural language processing have investigated and reported on the impact of language use and language competence in aviation accidents [4], [5].

In the context of air traffic management, errors in clearance, traffic information or weather are causal factors in more than 30% of landing accidents. On the other hand, the involvement of controller-pilot communication errors is more than 60% as a causal or circumstantial factor in air accidents or incidents [6] . An analysis of the Air Safety Reporting System (ASRS) database shows how the different modes of controller-pilot communication are affected: listening errors account for 45%, while speaking errors account for 30% (e.g., inadequate clearance, weather information or emergency flight assistance), as shown in Table 1.

Table 1. Modes of communications affected in ASRS data [7]

Mode of Communication	Percentage of Reports
Listening	45%
Speaking	30%
Reading and writing	25%

In order to reduce the number of communication errors, the International Civil Aviation organization (ICAO) has specified strict rules governing communication between pilots and air controllers, as shown in the Figure 1.

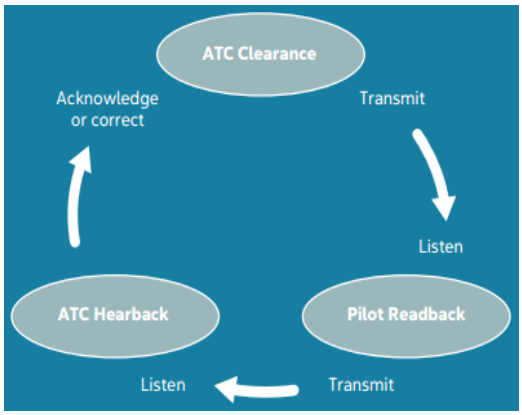

Figure 1. Controller-pilot communication loop [7]

This communication loop is designed as a confirmation and correction process to enable reliable communications. When adverse circumstances are likely to affect communications, adherence to this closed loop provides a barrier against communication errors [7]. Indeed, when an aviation emergency is declared, it is mandatory to think quickly and act immediately [8].

The air traffic controller therefore does not have enough time to make communication errors and the communication loop alone cannot be effective in this kind of unusual situation where every second counts. The lack of time and qualified people negatively influences situational awareness and decision making. In this kind of stressful situation, the poor communication of air traffic controllers is directly related to lack of practice and obsolete skills.

In recent years, the application of automatic speech recognition in the field of communication is becoming more and more requested and it is proving to be an excellent tool for the development of verbal communication skills [9]. Therefore, it is time to design new systems based on automatic speech recognition that will allow the development of an efficient aeronautical phraseology [10]. The objective of this study is to design and analyze a new specialized corpus of aeronautical phraseology for use in an intelligent communication system that should recognize phraseology errors made by student air traffic controllers when handling abnormal and emergency situations. The research was conducted with students in the third year of air traffic control engineering in the 2020/2021 academic year, at the Mohammed VI International Civil Aviation Academy (AIAC).

Our paper is organized as follows: first, we present an overview of the communication system based on automatic speech recognition. Then, we propose a new corpus specialized in controller-pilot interactions during the management of abnormal and emergency situations. Finally, we discuss the results and conclude our work by highlighting the direction of our future studies.

2. RESEARCH METHOD

2.1. Intelligent Communication System

In order to promote the use of the phraseology recommended by the International Civil Aviation Organization (ICAO) and to develop solutions to alleviate the linguistic anxiety of air traffic controllers in abnormal and emergency situations (ABES) [11], a new intelligent communication system based on automatic speech recognition has been designed to be used for training and assessment of the communication skills of student air traffic controllers [10]. Figure 1 shows part of the system architecture which highlights the corpus element in the architecture of the intelligent communication system. The input to the system is the student's speech and a predicted phraseology list from the newly designed corpus. In a second step, the student's speech is compared to the word sequences of the corpus to detect errors.

In systems engineering, a scenario is seen as a possible behavior limited to a set of interactions between several agents [12] or as a sequence of interactions between the system under consideration and its environment stated in the restricted context of a particular goal [13], [14]. For an emergency or abnormal situation, this dynamism will depend on the interactions of the scenario with the responses of the participants. Table 2 presents an example of the weather hazard scenario.

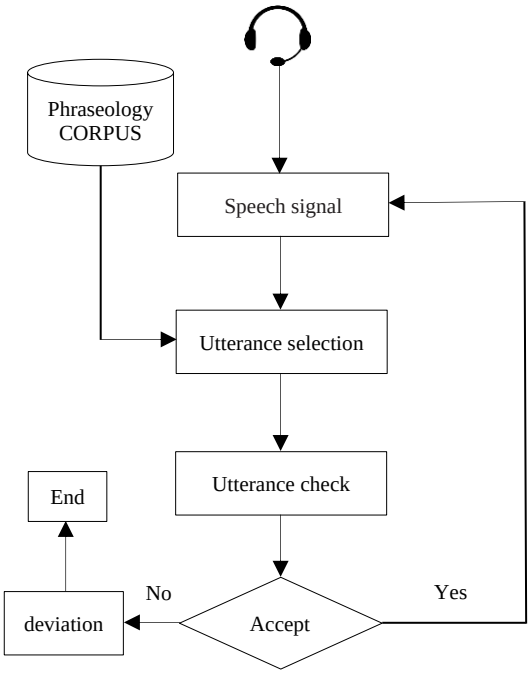

Figure 2. System architecture

Table 2. Example of Weather hazards scenario

Speaker	Utterance
Pseudo Pilot	PAN-PAN, PAN-PAN, PAN-PAN weather deviation required.
Student	Roger PAN, Descend flight level to 320.
Pseudo Pilot	Descending flight level 320.
Student	Report cleared of bad weather.
Pseudo Pilot	Roger

Source: Produced by the author

An emergency call is prefixed by the word "PAN PAN". Emergency messages have priority over all transmissions except distress messages. The words "PAN PAN", as appropriate, should be spoken preferably three times at the beginning of the initial emergency call[15].

The student responding to an aircraft in a weather hazard situation should first try to recognize the phrase "Roger PAN"and speak slowly and clearly to avoid unnecessary repetition.

The student should also optimize the time of the transmission of the necessary information and instructions. Wasting time repeating messages and finding the right phraseology to be understood will reduce the efficiency of the air traffic controller, cause misunderstandings and the situation can escalate quite quickly.

Thus, the intelligent communication system not only identifies speech errors but also measures the time spent on emergency management[10].

2.2. Corpus Collection

The intelligent communication system is intended to be tested and applied at the Mohammed VI International Civil Aviation Academy (AIAC) as part of the initial training. The objective of this paper is to design and analyse a

specialised corpus of aeronautical phraseology for subsequent incorporation into the intelligent communication system.

The first step was to compile a corpus from real recordings of air traffic control pilots' communications, transmitted on the three frequencies of the three sectors of the Casablanca flight information region: 125.5 MHZ for the North sector, 126.7 MHZ for the South sector and 125.1 MHZ for the East sector, in order to extract the phrases used in emergency or abnormal situations. However, it has been found that many air traffic controllers (ATCOs) can go long periods of time without having to deal with such unusual situations. To remedy this rarity, it was decided to develop a new corpus of phraseology from transcripts of practical exercises in training simulators at the Mohammed VI International Civil Aviation Academy (AIAC).

From 2021, we have started to build up a database of student air traffic controllers' communications from simulation exercises representing a full contextual scenario of abnormal and emergency situations in which students have to apply and use standard and correct phraseology [16].

The students responsible for the audio transcription of the practical exercises were informed of the purpose of the research and given the following instructions:

- Complete a form in a file under the name "AECC Identification"indicating the date, flight number, type of aircraft and nature of the emergency as well as the duration of the transcript.
- Save the transcript of the controller/pilot interaction of the practical exercise in the same file.
- Transfer only the transcripts relating to the emergency or abnormal situation to another Word file under the name "AECC Corpus".

In terms of the time invested in the transcription process, this is typically one hour of writing for every minute of recording. Thus, a new corpus called the Academy English Conversation Corpus (AECC) was designed. The corpus has (so far) thirty-six transcripts from twelve students (seven female and five male) who were asked to participate in three different scenarios: (i): loss of separation between two aircraft during initial climb, (ii): failure of ground-to-air communication, (iii): overflying a prohibited area due to bad weather conditions. The language used in the students' communications was English, the official and most used language in aviation [17].

3. RESULTS AND DISCUSSIONS

Once the transcriptions were made, the AECC corpus was analyzed using WordSmith Tools 07 (2019), a popular corpus analysis software available free of charge that allowed to define the behavior of words in texts. The tools used are Concord, WordList and the KeyWords tool[16]. The WordList tool displays a list of different words in the text, sorted by frequency or alphabetically. The KeyWords and Concord tools offer the possibility to find any keyword or phrase in their contexts.

Once the word lists are displayed, they can be saved in an excel file. AECC totaled 12282 tokens and 598 types and The Type-Token Ratio (TTR) is expressed as the following equation, where D is the number of types and N is the number of tokens [19]:

$$\text{Type-Token Ratio } (TTR) = D/N \times 100 \quad (1)$$

The Type-Token Ratio (TTR) of the AECC corpus is equal to 4.87, the low TTR is an indicator of a low degree of lexical variation, which can be explained by the fact that the interactions in the aviation domain are brief and concise. Figure 2 shows the 20 most frequent words.

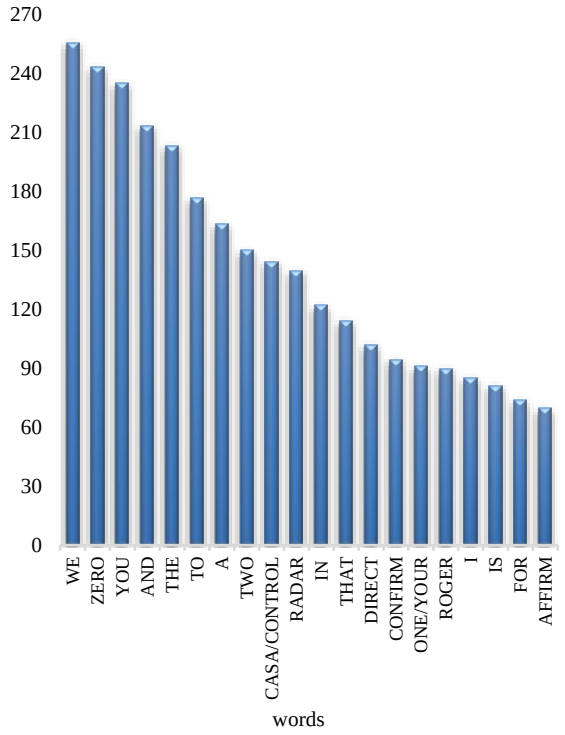

Figure 3. The twenty most frequent words in AECC

The results show that in the first seven positions, we find practically only pronouns, articles and prepositions whose frequencies are respectively 256 for "we", 235 for "you"213 for "and", 203 for "the", 177 for "to"and finally 163 for "a". The only most frequent number is "zero"which occupies the second position with a frequency of 243. These results are similar to those of Prado for his Radiotelephony Plain English Corpus (RTPEC)[20]. However, the first open class words are the call sign of the air traffic control service station "Casa Control", which is in ninth position with a frequency of 144 as shown in Figure 2. Additionally, Figure 3 shows the pronominal occurrences in the AEEC corpus, the results show that the top two pronouns in the list are the pronoun "we"and the pronoun "you". The pronoun "we"has a keyness value of +239.53 and the pronoun "you"has a keyness value of +176.48, coming in second, which is significant compared to all other words in the corpus.

Sexton and Helmreich (2000) also pointed out that the use of "we"seemed to increase under air traffic workload and that this use could be increased in stressful situations

[21]. These results suggest that the data collected is sufficiently reliable to be used. The use of "you"can be a singular or plural pronoun. This flexibility explains its high frequency. The student air traffic controller may use "you"when addressing a pilot, to request the delivery of an instruction (e.g., turn, climb, descend, accelerate) or to obtain information such as the pilot's intentions, number of passengers on board and the remaining fuel. Table 3 is an extract from the AECC corpus, which shows how the terms "we"and "you"are used in abnormal situation.

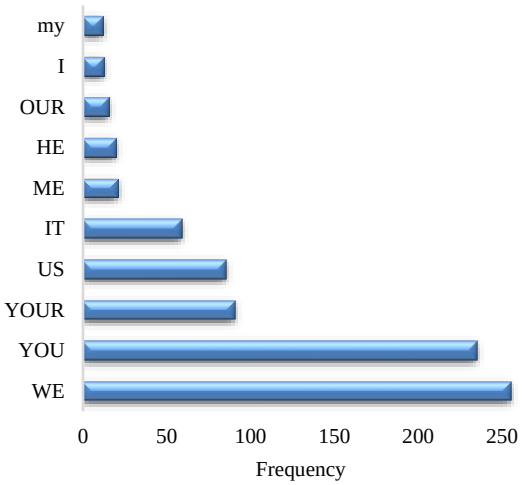

Figure 4. The twenty most frequent words in AECC

Table 3. Extract of the use of the pronouns "we" and "you"

Speaker	Utterance
Student	CNTNL, descend to 900 feet, QNH 1013 runway 20 in use
Pseudo Pilot	Casa control, Descending 2900 feet, QNH 1013 runway 20 in use, CNTNL.

Source: Produced by the author

Time pressure affects the interactions of student air traffic controllers, which leads to rushed and unsystematic communication, as shown in the Table 3. The read-back function was not respected to prevent the flight level error from occurring and the use of many paired communicative functions (e.g., expression of politeness paired with an instruction) led to misleading communication. This type of rushed and unsystematic communication is usually due to lack of practice and stress, the student uses simple English instead of correct phraseology when communicating.

A closer analysis of the word groups in the AECC corpus also shows the presence of homophony such as the word "to"and "two". This use of homophony has led to fatal errors. Table 4 shows an extract from the AECC illustrating an incident that occurred due to the misuse of the word "to". In this instruction, the similarity between "to"and "two"led the pilot to understand 2900 feet instead of 900 feet. These types of communication errors can cause serious incidents.

Although the Academy English Conversation Corpus (AECC) is limited, as aeronautical phraseology is a simple coded sub-language with a standardized vocabulary, it should be noted that this type of corpus offers greater ease of identification of specialized terms and collocations, making concordance more representative and more usable.

Table 4. Extract from the use of the pronouns "to" and "two"

Speaker	Utterance
Pseudo Pilot	We are experiencing moderate turbulence.
Student	Will you let me know your intentions for the flight level change?
Pseudo Pilot	Wilco.
Student	Copy that. If you want, you can descend to level 340.
Pseudo Pilot	We cross level 330 to level 320.
Student	Uh no, sir, you are not allowed to descend to level 320. Climb immediately to level 340.

Source: Produced by the author

4. CONCLUSION

Our research consists of developing a specialized corpus of aeronautical phraseology for use in an intelligent communication system that should recognize phraseology errors made by air traffic controllers when managing emergency and abnormal situations.

The research was conducted in an air traffic control (ATC) simulator environment at Mohammed VI International Civil Aviation Academy (AIAC), involving third-year air traffic control engineering students during the 2020/2021 academic year.

As a result, a new corpus called Academy English Conversation Corpus (AECC) was designed and analyzed. The AECC totaled 12282 tokens and 598 types with a Type-Token Ratio equal to 4.87. Concretely, the AECC corpus can be considered as:

- Specialized corpus: it represents a particular and specific context; it essentially covers communication procedures for abnormal and emergency situations in air traffic management.
- Reference corpus: the students have practically used the standard and correct phraseology of the International Civil Aviation Organization (ICAO). Thus, the new corpus can be described as a reference corpus that will serve as a basis for designing a communication system to identify possible phraseology errors.

Despite the limitations of the database so far, the corpus already offers us material for future research.

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REFERENCES

[1] K. Jenab, S. Moslehpour, S. Khoury, "Virtual maintenance, reality, and systems: A review", International Journal of Electrical and Computer Engineering, vol. 6, no. 6, p. 2698, 2016.

[2] B. Al Braiki, S. Harous, N. Zaki, F. Alnajjar, "Artificial intelligence in education and assessment methods", Bulletin of Electrical Engineering and Informatics, vol. 9, no. 5, pp. 1998-2007, 2020.

[3] L.V. Krivova V.Y. Ushakov, "Professional training in English - Discipline for master degree students of "digital technologies in power engineering program", International Journal on Technical and Physical Problems of Engineering, Issue 45, Vol. 12, No. 4, pp. 97-102, 2020.
[4] S. Cushing, "Fatal words: Communication clashes and aircraft crashes", University of Chicago Press, 1994.
[5] C. Linde, "The Quantitative Study of Communicative Success: Politeness and Accidents in Aviation Discourse", Language in Society, vol. 17, no. 3, pp. 375-399, 1988.
[6] H. Helmke, et al., "Readback Error Detection by Automatic Speech Recognition to Increase ATM Safety", Fourteenth USA/Europe Air Traffic Management Research and Development Seminar (ATM2021), Idiap Publications, p. 10, 2021.
[7] "Effective Pilot/Controller Communications", Flight Operations Briefing Notes, Human Performance, p. 17, Sept. 2004.
[8] N.G. Cagin, O. Senvar, "Anticipation in Aviation Safety Management Systems", YIRCoF'19, p. 9, 2019.
[9] C. Cucchiarini, H. Strik, "Automatic Speech Recognition for second language pronunciation training", Routledge handbook of contemporary English pronunciation, Routledge, p. 556-569, 2017.
[10] Y. Mnaoui, A. Najoua, H. Ouajji, "Conception of a Training System for Emergency Situation Managers", The 1st International Conference on Innovative Research in Applied Science, Engineering and Technology (IRASET), pp. 1-4, Apr. 2020.
[11] J. Drayton, "The vocabulary of aviation radiotelephony communication in simulator emergencies and the contradictions in air traffic controller beliefs about language use", University Library Papers and Theses, Victoria University of Wellington, New Zealand, 2021.
[12] C.B. Achour, "Extraction of needs by analysis of textual scenarios", Political Science, 1999.
[13] C. Rolland, "Needs Engineering: The L'Ecritoire Approach", Technical Journal of the Engineer, p. 1, 2003.
[14] N. Tohidi, C. Dadkhah, R.B. Rustamov, "Optimizing Persian Multi-Objective Question Answering System", International Journal on Technical and Physical Problems of Engineering (IJTPE), Iss. 46, Vol. 13, No. 1, pp. 62-69, March 2021.
[15] T. Katerinakis, "Knowledgeable Sounds of Silence or When Silence Is Not Golden", Social Construction of Knowledge in Mission-Critical Environments, Springer, pp. 91-135, 2019.
[16] U. Kale, I. Jankovics, A. Nagy, D. Rohacs, "Towards Sustainability in Air Traffic Management", Sustainability, vol. 13, no. 10, p. 5451, 2021.
[17] R. Fowler, E. Mathews, J. Lynch, J. Roberts, "Aviation English Assessment and Training", Collegiate Aviation Review International, vol. 39, no. 2, p. 26, 2021.
[18] M. Scott, "WordSmith tools manual version 7.0", Stroud Gloucestersh Lexical Analysis Software Ltd., 2019.
[19] M. Paquot, "The phraseological dimension in interlanguage complexity research", Second Language Research, vol. 35, no. 1, pp. 121-145, 2019.
[20] M.C. de Almeida Prado, "Corpus of Oral English in Aviation in Abnormal Situations", Tradterm, vol. 37, no. 1, pp. 148-174, 2021.
[21] J.B. Sexton, R.L. Helmreich, "Analyzing cockpit communications: the links between language, performance, error, and workload", Human Performance in Extreme Environments, vol. 5, no. 1, pp. 63-68, 2000.

BIOGRAPHIES

Youssef Mnaoui was born in Mohammedia, Morocco in 1980. He is a Ph.D. student at ENSET Institute, University of Hassan II Casablanca, Morocco since 2018. Since 2004, he is an air traffic controller at the National Airports Office in Casablanca, Morocco. Since 2018, he is an Air Traffic Control Simulator Instructor and also teaches the course of Air Investigation and Accidents at Mohammed VI International Civil Aviation Academy, Casablanca, Morocco. His research is focused on simulation, technology teaching systems, training system air traffic control communication, air investigation and accidents.

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