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Automatic Reading of Aeronautical Meteorological Messages

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Abstract. This paper describes the architecture developed to produce an automatic reader of aeronautical meteorological messages. An interlingua has been used and a whole process of natural language generation has been implemented. The system Festival has been used with a modified voice to read the messages generated. The presented system is able to translate the meteorological messages into a natural language text and read it.

Keywords. Aeronautical meteorological messages, interlingua, data flow diagrams, natural language generation, voice generation.

Introduction

This paper describes the general lines of a system developed for the automatic reading of aeronautical meteorological METAR and SPECI [1] [2] messages. The main purpose of this paper is to mark the different techniques we have used to treat the raw message and transform it into a natural language text that can be read using a modified voice of Festival [3].

The METAR (METeorological Airport Report) and SPECI (Special Meteorological Aeronautical Report) messages code the information about the metrological situation at the airports [1] [4]. This information has to be understood by the pilot and has to be read in a decoded way at the ATIS (Automatic Terminal Information Service) [5] frequency of the airport. So, a system as described here can be useful to help the pilot to understand the messages and can be implemented as a part of an automatic ATIS generation.

Nowadays we can find some systems that help us to decode the METAR messages like the one we find in meteofrance.fr [6]. These systems decode for us, in a very simple way, the information coded in the METAR message but it does not produce any kind of text generation. Other systems, like the developed by Computer Network Design [7], can be used to do an automatic ATIS. This system can analyse the meteorological information from the automatic weather observing system (AWOS) [8], but it does not analyse the METAR messages. Moreover, it allows the user to generate speech from text using the speech application programming interface of Microsoft (SAPI) [9], but when we want to do a fully automatic ATIS this kind of systems use a pre-recorded library of words and phrases. Even if these systems can be useful they are too rigid and all the phrases will be generated in the same way. The system we propose here allows us to generate text in a natural way from the METAR messages and later read the text generated using the Festival system.

This paper is divided in 8 sections: First of all, the reader can see the problematic about the meteorological messages for aeronautics and the interest in their automation. Sections 2 and 3 offer an overview of the specification of the system and its architecture. The translation of a message into a natural language text and the connexion with Festival is described in section 4. The work done in Festival to produce speech generation adapted to meteorological messages is described in section 5. Some examples of use are shown in section 6. Further work and conclusions close this paper.

1. Meteorological messages

The METAR, SPECI and TAF [1] [2] (Terminal Aerodrome Forecast) messages are generated by the meteorological observatories located at the airports. The METAR messages are created regularly each fixed interval of time. If the situation changes between two METAR messages then a SPECI message would be generated. The TAF messages give to the pilot the information about how the weather will evolve in the following hours. The METAR, SPECI and TAF messages code the information in a very

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specific way. So using a specific code all the meteorological information is represented. [10][11][12] All the messages have a group of information where is coded the identification of the airport, the date and the hour of the message, the information about the wind in the surface, the visibility, the clouds and the atmospheric pressure. The message will code also if any situation like rain, storms, fog, etc. is produced. The METAR message can have information about how the situation will evolve in the following hours (this is the TREND part of the message). Sometimes if the runway change its characteristics due to the meteorological situation this information is coded also in the METAR message, for example if due to the rain the coefficient of friction of the runway change it can be also coded in the message.

Once these messages are created they are diffused with the NOTAM (Notice To Airmen) information, which inform about the situation of the airport: runway used, if a taxiway is closed, etc. The meteorological information is crucial for the coordination and the development of the operations of approach and landing.

Nowadays the ATIS give this information. The radio transmitter is used to broadcast the information that could be important for the airplanes that operate close to the airport. The ATIS information is changed each time the meteorological information or the airport information is changed. In order to minimize the errors due to the few quality of the radio transmission, many research groups are working on the possibility of transfer all the information relevant to the flight (messages and orders given by controllers) by data-link between the ground and the plane [13]. Thus, the information will arrive coded to the plane and a system on board would show/read it to the pilot. In the same way as the METAR, SPECI and TAF information, the SIGMET [1] (Significant Meteorological Forecast) is sent to the plane to help them to navigate avoiding adverse meteorological phenomenon. In the Figure 1 we can see the flow of information.

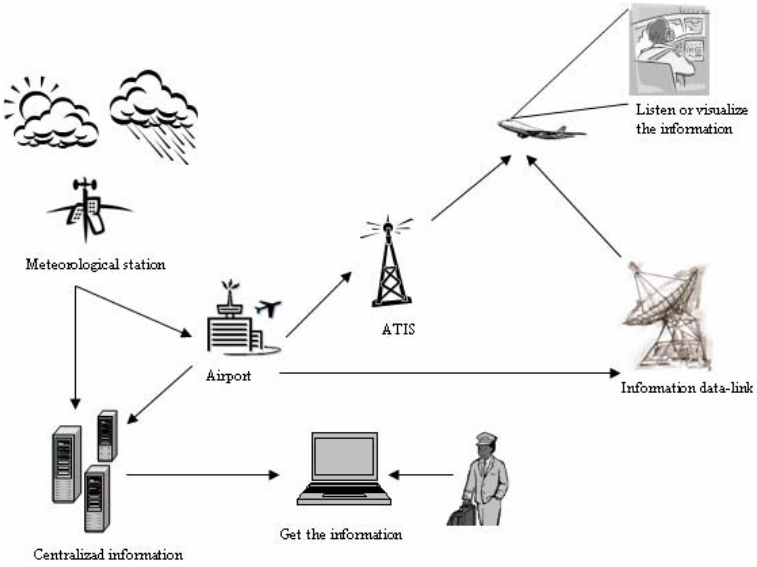

Figure 1. Flow of information

2. System specification

The system we have developed does the translation to natural language of the messages METAR and SPECI. This text generation is followed by a reading of it (speech synthesis). The translation and reading has been done in Spanish. However, the system has been developed in a way that allows the addition of a new language in a very simple way.

For the lecture of the message, our system is connected to Festival [3]. Festival is a framework that allows us to develop our speech synthesizer. Festival has been created by the University of Edinburgh and uses the library Speech Tools Library. The Festival Spanish voice has been modified in order to adapt it to the domain of aeronautical meteorological messages.

3. System architecture

From a functional point of view, the system is divided in three parts (Figure 2.)

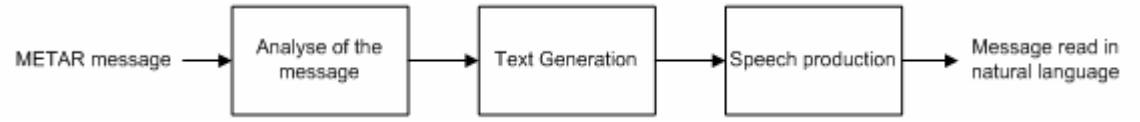

Figure 2. Functional view of the system

1. Analyse of the message to extract the information.
2. Generation of the text in natural language.
3. Synthesization of the voice to read the generated message.

To maximize the characteristics of modularity, reusability, maintainability, just as the easiness of expansion, the system has been developed in three layers and each one has different packages. (Figure 3.)

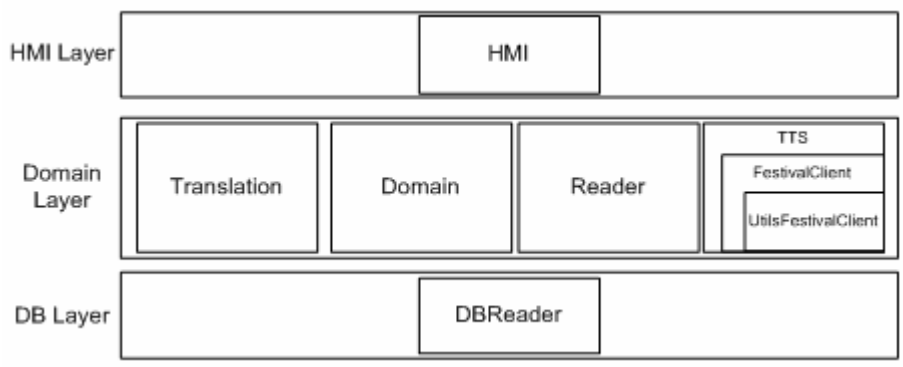

Figure 3. Architecture of the system

- The HMI (Human Machine Interaction) package ensures the interaction with the user.
- The package of Translation analyzes the METAR and SPECI messages.
- The Domain package has the information that is used to represent the information contained in the meteorological message.
- The Reader will generate the text.
- TTS (Text To Speech) and its subs-packages connect our system with Festival to produce the read of the message.
- The DBReader package will connect the Domain Layer with the database that contains the information about the name of the airports.

The Figure 4 shows how the information is sent to Festival to produce the read message.

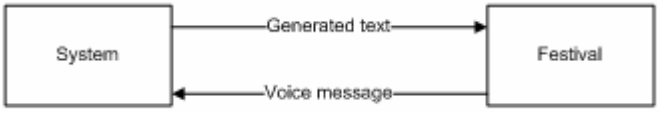

Figure 4. Interaction of the system with Festival

3.1. Analyse of the METAR and SPECI message

As we have said the METAR and the SPECI messages are coded in a very specific way. So, a very simple first version of a system could be as direct as a transducer. (Figure 5.)

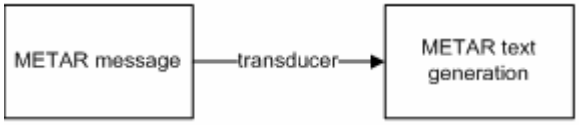

Figure 5. Simple version of the system

However, with this approach we would obtain a solution too much rigid. Our idea is to have a system the most adaptable to changes, so if we change the language we don't want to redo the analysis. For this, we have chosen to pass throw an interlingua. The analysis of the message will be an automat that will parse the message and will construct an intermediate structure with all the information contained in the

message. Later, the text generator will use theses structures to generate the text in the most natural way as possible. This data flow is shown in the Figure 6.

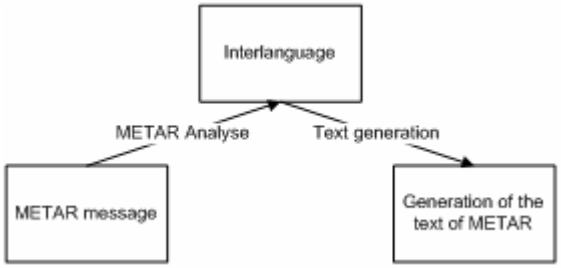

Figure 6. System with an interlanguage

The interlingua is defined as a group of classes with relations between them. These classes represent the information that the meteorological messages could have. Using an interlingua has many benefits: it will allows us to rewrite the message without redoing the analysis. It is useful if we want to obtain different texts generated for the same message. It is also useful because we can use this intermediate structure to other purposes than the transduction to natural language. Once we have decoded the message, this information could be used to do other tasks than give the plain meteorological information to the pilot. So, for example, it could be used to help in the computation of routes on ground or, to decide which airport with an adequate meteorological situation is the closest if the meteorological situation is degraded very fast in a VFR (Visual Fight Rules) flight. This information could be used also to detect, in an automatic way, risky situations (storms, low visibility, strong winds perpendiculars to the axis of the runway, etc), this kind of information would be very useful to the light aviation where the planes are not so equipped as the commercials ones.

The interlingua has an additional interest in the fact that we have separated the analysis of the message from the text generation. This allows us to change the generated text language without changing the analysis.

3.2. Text Generation

Once the message has been analyzed and translated into the interlingua, the text is generated by the Reader package. This package would have one implementation of the reader for each language. It will use the information contained in the interlingua to produce a text the most natural as possible.

3.3. Voice Synthesis

As we have already said, the voice synthesis will be done with Festival. For this purpose the package TTS will connect with Festival that will be executed as a server.

4. System design

4.1. HMI layer

The interaction with the user is done by the package HMI. Its responsibility is to generate the interface and communicate the instructions to the domain layer. With this interface, the use of our system is very simple: the user introduces the METAR or SPECI message and asks the system to translate it or to translate and read it. The system will call to the analyzer who will translate the message to the interlingua. Later, the reader will generate the text in natural language and the TTS package will connect to Festival to produce the voice synthesis.

4.2. Domain layer

This layer is the most important and has four components: translation, domain, reader and TTS.

In this layer we will find the code that implements the automat that analyse the message and generates the message information in the interlingua.

As we have said, the interlingua is defined as a group of classes with relations between them. The number of classes and relations could be very important but the benefit we obtain is worth.

We have tried to generate the text the most natural as possible. If we ask to different people to decode and read a message we will check that everyone will read it in a different way. So if we want a system that produces fully natural language we have to introduce some randomness. However the kind of messages we have to generate are reduced to a very specific domain, so we don't need a very complicated system like the one we could find in a text generator for automatic summary [14][15]. An easy but effective way we have found to model this is the use of data flow diagrams. There's a data flow diagram for each fragment of the message. This allows us to have a system that generates, for a same interlingua, different messages but reduce the points of connexion between the different parts generates. So, it simplifies the modelling of the text generation. We can have a data flow diagram at a level of paragraphs and decompose it in many small diagrams to produce the phrases.

The Figure 7 shows a part of the grammar that we have used to generate a part of the message. This grammar could be shown as a data-flow diagram. To work with these diagrams is also useful from a point of view of software engineering because it is helpful to control the different kinds of messages that can be generated and it is very easy to split the problem of generation of big messages in small parts.

ReadWind → SignificantWind | NotSignificantWind
SignificantWind → StrongerThan40kts | NotStrongerThan40kts
StrongerThan40kts → **"hay un día ventoso con vientos"** WindModificator
WindModificarot → **"superior a"** QuantityAndUnit GustTreatment |
"inferior a" QuantityAndUnit GustTreatment |
"de" QuantityAndUnit GustTreatment
GustTreatment → Gust | VariableDirectionTreatment
Gust → **"con ráfagas de"** QuantityAndUnit VariableDirectionTreatment
VariableDirectionTreatment → **". El viento tiene dirección variable"** |
NotDirectionVariable
NotDirectionVariable → **"del"** CardinalPoint **"("** Degrees **"grados)"** |
"de" Degrees **"grados"**
NotSignificantWind → **"el viento esta calmado."** |
"no hay viento significativo."

Figure 7. Part of the grammar used to generate the messages

With the grammar shown in Figure 7, we can generate different natural language texts for the part of the message that indicate when the wind is strong. For example the part of the METAR message: 12012G43K has the information that the wind comes from 120 degrees with strength of 12 Kt and with gusts of 43 Kt.

To use the grammar we choose the text generated in function of the values of the message coded in the interlingua and in a random way when many alternatives are possible. So we could generate a message like *"hay un día ventoso con vientos de 120 nudos con ráfagas de 43 nudos que proviene de 120 grados" "there is a windy day with wind strength of 120 knots with gusts of 43 knots that comes from 120 degrees"* or *"hay un día ventoso con vientos de 120 nudos con ráfagas de 43 nudos que proviene del sureste (120 grados)" "there is a windy day with winds of 120 knots with gusts of 43 knots that comes from the southeast (120 degrees)"*.

Once the text is generated we can connect our system with Festival. So, the steps, the system will do if we ask him to read the text, would be:

1. Creation of the session.
2. Initialization of the system Festival.
3. Ask Festival to use the voice_em_diphone.
4. Give to Festival the text to read.
5. End the session.

The voice_em_diphone is a modified version of the Spanish voice that we can find in Festival. As we will see this voice has been adapted in order to treat the meteorological messages.

4.3. Database layer

The database has the information of the ICAO (International Civil Aviation Organisation) code, name, city and country of all the airports [16][17]. So if the text generator wishes, it can ask the database any information about the airport to add it to the generated text.

5. Speech synthesis with Festival

Festival is a system to convert text to speech developed at University of Edinburgh. It has many voices by default. We have chosen to modify the voice_el_diphone to create the voice_em_diphone.

The voice voice_em_diphone works as the diagram Figure 8 shows:

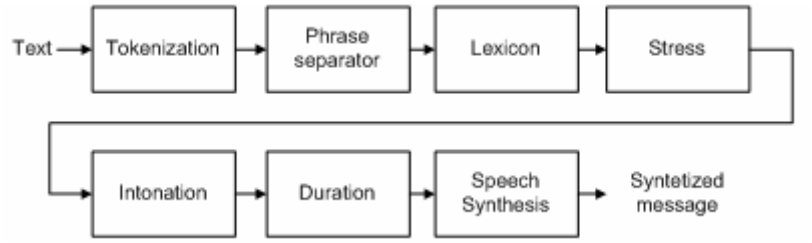

Figure 8. Use of the voices of Festival

So, one voice is composed of :

- Phoneset: basic bloc of construction of a voice.
- Lexicon: set of words associated with their phonetic pronunciation, or letters associated with their phonological symbol.
- Phrase separator: It is used to determine when a phrase starts and ends.
- Duration: The duration of each phoneme will be decided here.
- Signal synthesizer: We can use a system like MBROLA [18] or one phoneme database pre-recorded.

To adapt the Festival voice by default (voice_el_diphone) we have work on the tokenization stage. Here tokens like *<"21">* are modified to their pronunciation *<"veintiuno">*. We have had some functions that allow to:

- Change a group of four capital letters to their international radio language to read the ICAO codes of the airports. So *<"AHOD">* will be changed to *<"Alfa" "Hotel" "Oscar" "Delta">*.
- Read the units and speed: *<"kt">* to *<"nudos">*,*<"mph">* to *<"millas" "por" "hora">*, etc.
- The hours are changed by their numbers: *<"21:11">* will be *<"22" "11">*.

We have had some words to the lexicon to try to improve the pronunciation. But due to the fact that the actual implementation of our system is in Spanish it is not very useful. We don't see a great improvement because the translation done by Festival of the words in Spanish to their phonemes is good enough.

6. Examples of use

Here we can see many messages and how the text is generated in different ways, in Spanish we can see the text generated by the system, in English its translation to a better understanding.

LEBL 172000Z 26005KT 210V010 9999 FEW025 SCT080 BKN170 26/17 Q1019 NOSIG

"Mensaje Metar del día 17. En el aeropuerto LEBL, a las 20:00 hora zulú, el viento viene del oeste (260 grados), con dirección variable entre 210 y 10 grados. El viento tiene una fuerza de 5 Kt.
La visibilidad es superior o igual a 10 kilómetros.
Hay escasas nubes a 2500 pies, nubes dispersas a 8000 pies y nubes fragmentadas a 17000 pies.
La temperatura es de 26 grados, la temperatura de punto de rocío es de 17 grados. La presión es de 1019 hectopascales."

"Metar message of the 17th. At the airport of LEBL, at 20:00 hours zulu, the wind comes from the west (260 degrees), with variable direction from 210 to 10 degrees. The wind has strength of 5 knots.
The visibility is bigger or equal to 10 kilometres.
There are few clouds at 2500 feet, scattered clouds at 8000 feet, broken clouds at 17000 feet.

The temperature is 26 degrees; the dew point is 17 degrees. The pressure is 1019 hectopascals."

"Mensaje Metar del día 17 del mes actual. En LEBL, a las 20:00 horas zulú, hay un viento de 5 Kt, la dirección del viento es de 260 grados, con dirección variable entre 210 y 10 grados.

La visibilidad es superior o igual a 10 kilómetros.

Hay escasas nubes a 2500 pies, nubes dispersas a 8000 pies y nubes fragmentadas a 17000 pies.

La temperatura es de 26 grados y la temperatura de punto de rocío es de 17 grados. La presión ambiente es de 1019 hectopascales."

"Metar message of the 17th of he present month. At LEBL, at 20:00 hours zulu, there is a wind of 5 knots, which directions is 260 degrees, the direction is variable between 210 and 10 degrees.

The visibility is bigger or equal to 10 kilometres.

There are few clouds at 2500 feet, scattered clouds at 8000 feet, broken clouds at 17000 feet.

The temperature is 26 degrees and the temperature of the dew point is 17 degrees. The environment pressure is 1019 hectopascals."

METAR LFPO 101300Z 270P10G25KT 9999SW 6000NE R29/0500N TS SN +TSRAGR vv345 OVC120TCU 18/12 Q2003

"Mensaje Metar del aeropuerto LFPO. El día 10 del mes actual, a las 13:00, el viento viene del oeste (270 grados) con una fuerza superior a 10Kt con ráfagas de 25Kt.

La visibilidad es superior o igual a 10 kilómetros dirección suroeste, con visibilidad máxima de 6 kilómetros dirección noreste. La visibilidad en la pista 29 es de 500 metros, no se esperan cambios.

Hay tormenta, nieve y fuerte lluvia con granizo.

El cielo está oscurecido a 34500 pies y cúmulos de desarrollo vertical cubren todo el cielo a 12000 pies.

La temperatura es de 18 grados, la temperatura de punto de rocío es de 12 grados. La presión ambiente es de 2003 hectopascales."

"Metar message of the airport LFPO. The 10th of the present month, at 13:00, the wind comes from the west (270 degrees) with strength bigger than 10 knots with gusts of 25 knots.

The visibility is bigger or equal to 10 kilometres direction southwest, with maximal visibility of 6 kilometres direction northeast. The visibility of the runway 29 is of 500 meters, no changes are expected.

Overcast at 34500 feet and cumulus of vertical development overcast the sky at 12000 feet.

The temperature is 18 degrees, the the temperature of the dew point is 12 degrees. The environment pressure is 2003 hectopascals."

"Mensaje Metar del día 10 a las 13:00. En el aeropuerto LPO, el viento viene del oeste (270 grados) con una fuerza superior a 10Kt con ráfagas de 25Kt.

La visibilidad es superior o igual a 10 kilómetros dirección suroeste, con visibilidad máxima de 6 kilómetros dirección noreste. La visibilidad en la pista 29 es de 500 metros, no se esperan cambios.

Las condiciones meteorológicas actuales son tormenta, nieve y fuerte lluvia con granizo.

El cielo esta oscurecido a 34500 pies y cumulocongestus que cubren todo el cielo a 12000 pies.

La temperatura es de 18 grados, la temperatura de punto de rocío es de 12 grados. La presión ambiente es de 2003 hectopascales."

"Metar message of the 10th at 13:00. At the airport LFPO, the wind comes from the west (270 degrees) with strength bigger than 10 knots with gusts of 25 knots.

The visibility is bigger or equal to 10 kilometres direction southwest, with maximal visibility of 6 kilometres direction northeast. The visibility of the runway 29 is of 500 meters, no changes are expected.

Overcast at 34500 feet and there are cumulucongestus that cover the sky at 12000 feet.

The temperature is 18 degrees, the the temperature of the dew point is 12 degrees. The environment pressure is 2003 hectopascals."

7. Further work

Many modifications and extensions can be done to our system. Thanks to the use of the interlingua it is very easy to add news languages.

Nowadays there are many internet sites that offer the meteorological information in real time [19][20][21]. So it would be interesting connect our system to one of this sites. If we do it, only with the ICAO code of the airport we could get the meteorological message and obtain a translation to natural language.

The actual system analyse and generate the text for the METAR and SPECI messages, but it already detect if the messages are METAR, SPECI, TAF or SIGMET. So it would be interesting to extend the system to treat the kind of messages that are not already fully analyzed. A huge part of the interlingua could be reused and the Festival voice will be also useful.

As we have emphasized in this paper, our system could be use as a part of a bigger system that does the ATIS in an automatic way or it could be used as a part of a system that would read the information to the pilot when it arrives to the plane with the data-link.

A system that translates the aeronautical meteorological messages to natural language would be also useful to train the pilots to analyze this kind of messages.

Finally, the information decoded that we store in the interlingua could be used to other purposes like the compute of routes to avoid to pass through adverse areas, alarm systems that could alert when the weather situation is dangerous (storms, strong wind,…), etc.

8. Conclusion

In this paper we have described the main ideas of the software we have developed to do the translation and lecture of aeronautical meteorological messages. We have pointed out the advantages of using an interlingua. This will allow to use the decoded information of the message to other purposes than the text generation and will help to add new languages in a very easy way.

We also consider that the use of data flow diagrams to model the text generation is a very good methodology. It has made possible to have a view of the whole text generator system and to add new phrases in a very easy way. It is useful to decompose the generation of the text in the generation of paragraphs that could be decomposed in the generation of phrases.

Our system differs from the existing ones that it can generate fully natural text to express the meaning of the aeronautical messages and the use of a system like Festival to generate the speech synthesis allows us to have a more natural speech generation.

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