Building a Corpus for Cockpit Voice Recorder Transcripts

in the project seminar

Computational Natural Language Systems

RVS-Occ-01-06

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1 Overview

Cockpit Voice Recorder (CVR) transcripts are a valuable tool when studying aviation incidents. It is not always necessary to have the original audio recording, since often it suffices to be able to understand the process of the talks between involved persons.

In their original (released) format, the CVR transcripts are only little formatted. They are usually plain text files encoded in ASCII. They consist of lines, each line containing both information about the speaker of the message, the time when it was spoken and the message itself. In most cases, this information is separated only by blanks.

Our object is to provide an adequate corpus format for these transcripts for automated processing, making it easier to annotate, search and compare CVR transcripts automatically. This format enables us to help potential users of the corpus (e.g. [2]).

2 Analyzis of the CVR transcripts

CVR transcripts are an important instrument in developing aviation safety. In their original plain text format the form of structure these documents have is that each line consists of three parts: a time code, a speaker and the actual transcribed message (see [5], [6] and [7]). Usually these parts are only separated by a blank, and sometimes not even this basic “standard” is used.

This kind of processing does not work very well with automated processing. Comparing them, annotating them, searching them, finding sequences and more with a computer system is not possible. It also means that the contained information which might be important for analyzing accidents is rather inaccessible.

2.1 Sentence/expression structure

As mentioned above, CVR transcripts are usually separated into lines. All lines contain a time code, a speaker and the message itself. The lines are consecutively ordered by the time code. For the speaker roles we identified different schemes for certain situations. In intra-cockpit communication, two schemes can be distinguished. The first scheme uses speaker roles such as “Captain”, “First Officer”, ”Pilot-In-Command” [6].

Example:

11:58:05	Capt	Altimeter 1014, MDA is 173, Set.
11:58:08	F/O	1014, MDA 173 set right, V bugs.

The second one simply enumerates the different recording sources (e.g. headphones) in use [7].

Example:

18:08:38	CAM-2	a little rudder.
18:08:39	CAM-1	all right.

Another scheme is utilized in transcripts of radio communication between a tower and different airplanes. Here the official calling signs identify the speaker [5].

Example:

16:14:59	ASA261	K Alaska two sixty one say again the frequency one two zero five two
16:15:03	R30	Uh Alaska two sixty one twenty six fifty two

Sometimes the last scheme is mixed with one of the first two if required.

The messages themselves can be made up of one or more sentences, although they are not always punctuated correctly. Since these documents are transcripts of spoken language, the sentences are often elliptic and may contain utterances and unintelligible words.

2.2 Tokens

After analyzing the sentence/expression structure, we took a closer look at the token level. The transcripts contain many technical terms special to aviation. Often these are grouped with common terms such as numbers, alphabets or directions.

We built a list of keywords intuitively by manually searching the transcripts for these technical terms. After we had done so with an initial transcript, we checked more transcripts against our list. When a potential keyword was not already in the list, it was added. Due to this iterative algorithm, we soon had a relatively stable list of keywords. We completed this list with the aforementioned numbers, alphabets, and direction identifiers, and then took a closer look at this list.

Since one of our objects is to analyze the semantic structure of the dialog, we must be able to determine the topics of the individual sentences. Together with the authors of [1], we came up with a number of categories. These included e. g. flight phases, parts of planes or airports, weather conditions and changes of the state of the plane (heading, speed, altitude). We also created a list of possible flight phases, such as *cruise*, *taxiing* and *descend* (see appendices C and D).

The keywords in our list then were annotated with both the meaning of the token, the contexts that its use could indicate and the flight phases it could occur in, and sorted alphabetically.

The syntax for an entry in the keyword list is

```
keyword[meaning][context][flight phase]
```

so it would look like this

```
runway[runway][radioNumeral][taxiing:takeoff:approach:descend:landing]
```

In this example *runway* is the word actually appearing in the transcript. It has the meaning *runway*, indicating that the speaker is talking about runways. Its context is *radioNumeral*, because runways are usually referred to by numbers, as in “runway 09”, so a numeral can be expected to follow in the transcript. The flight phases in this example are those dealing with the beginnig and the end of a flight, because that is when the crew usually talks about assigned runways.

2.3 Semantic structure

Semantic structure of the dialog refers to the relations between the different speech acts in the dialog, as opposed to the semantic structure in a single speech act.

With the categorisation of keywords it becomes possible to narrow down the number of possible topics of a message or sentence. This made it interesting for us to analyze the semantic structure of the dialogs, to figure out whether these topics indicate relationships between consecutive sentences.

Theses relations are usually of the kind *request-and-response* or similar dialog acts. We then began to determine typical signatures for these dialog acts and created a list of keyphrases that indicate whether the sentence they are part of are a request or a response. These keyphrases are not to be confused with the keywords as described in the last section. While the former usually consist of more than one word and indicate a certain speech act such as *request*, the latter are the technical terms found throughout the transcripts that help us determining the subject.

E.g. “Could you” is a typical keyphrase indicating a request, while “brakes” is a keyword in a technical context.

The transcripts we analyzed manually were the following (the first three transcripts are those we spent most of our time with):

- China Airlines Flight 676 (1998-02-16) (China 676)
- Alaska Airlines Flight 261 (2000-01-31) (AA 261)
- Airborne Express Flight 827 (1996-12-22) (AirEx 827)
- Air France Flight 4590 (2000-07-25) (Air France Flight 4590)
- UN Flight KSV 3275 (1999-11-12) (KSV 3275)
- Vladivostokavia Flight 352 (2001-07-04) (Vladivostokavia 352)

We looked for the following dialog acts:

- Statement with positive confirmation (state +)
- Statement with negative confirmation (state -)
- Question and answer (q / a)
- Request and response(s) (req / res)
- Statement and response(s) (state / res)

This resulted in the following figures (in percent):

	state +	q / a	req / res	state -	state / res
AirFrance 4590	22	0	67	5	6
UN Flight KSV 3275	20	0	80	0	0
China Air 676	30	11	57	2	0
Alaska Airlines 261	34	17	45	0	4
Airborne Express 827	19	19	31	0	31
Vladivostokavia 352	43	14	29	0	14

When we looked at the dialogs a little closer, we noticed that although these acts are different in form, they are pragmatically indistinguishable for our purpose.

One reason for this is the fact that there is a well defined chain of command. In such an environment, a statement like “the brakes need to be checked” by the highest ranking officer aboard is pragmatically a request or command to a lower ranking officer.

Also, for all involved it is clear that the situation appears in a technical environment. So the occuring speech acts in the CVR transcripts are limited in their variety.

Here are some examples that we give to show that for our work it is ok to merge the categories:

- *Question and Answer:*

  1. (from China 676)
     CAP Do you call them?
     F/O Yes.
     ⋮
     F/O Tower, Dynasty 676, 3 miles on final. Confirm clear to land.

This question resulted in the first officer calling the tower, so it is actually a request to call the tower.

2. (from Alaska Airlines 261)

R14	Do you see him up there high ahead and to your right?
SKW5154	Ah we're looking Skywest fifty one fifty four.

   Skywest is not really answering the question, but instead beginning with a new action as requested.

- *Statement and positive confirmation:*

1. (from Alaska Airlines 261)

ASA261	Our intention is to land at Los Angeles.
R25	Roger. You're cleared to Los Angeles airport via present position.

   The tower interprets the simple statement as a request, acknowledges it and grants the requested clearance.

2. (from Kosovo 3275)

CTL	You're number two to a much faster aircraft just ahead of you now.
RDO	Okay

   This can be interpreted as the tower requesting that the pilot lines up according to the aircrafts' speed.

Therefore, we will be merging the three categories of QuestionAndAnswer, StatementAndPositiveConfirmation and RequestAndResponse(s) into just one RequestAndResponse(s) category.
With the merged categories, we get the following figures (in percent):

	req / res	state -	state / res
AirFrance 4590	89	5	6
UN Flight KSV 3275	100	0	0
China Air 676	98	2	0
Alaska Airlines 261	96	0	4
Airborne Express 827	69	0	31
Vladivostokavia 352	86	0	14

When we add the corresponding numbers together, the overall share of that category in the total number of dialog acts calculates (statistically weighted) to approx. 91 percent. Thus we will only be analyzing RequestAndResponse(s) structures with our program.

3 Implementation

3.1 Languages we used

3.1.1 XML

The Extensible Markup Language (XML) is a subset of SGML (Standard Generalized Markup Language), apart from the possibility to construct a start- and endtag in the same brackets e.g. <document/ >, which is not permitted in SGML. The XML 1.0 specification is released as a recommendation by the World Wide Web Consortium [13]. Since then XML has become a universal syntax for defining non-proprietary document markup and data formats. The opportunity to design your own DTD (Document Type Definition) gives you a huge flexibility to use XML. This is one of the advantages of XML in contrast to HTML, just as the separation of content and styling, which is blurred in HTML.

The important case for our project is the provision of content management in XML. The styling component is secondary, but still - as opposed to HTML - mandatory. To show our results we chose CSS (Cascading Style Sheets), a presentation through XSL (Extensible Stylesheet Language) is also possible. By means of the stylesheet, formatting for different output media is possible, e.g. printer or screen. More important is the construction of a reasonable DTD, which must contain all the elements and attributes we will use to markup our CVR transcripts. Inside the XML document itself, you need to refer to the DTD to which the document is suited.

3.1.2 Perl

Perl stands for “Practical Extraction and Report Language”. It has become a general purpose programming language, but it is most widely used for serious text processing. Because of its regular expressions, Perl is very powerful in searching and manipulating texts, and this is the main advantage for us to use perl as our programming language.

3.2 Design of the XML structure

For a well formed XML structure a DTD which is based on a context free grammar is essential. This context free grammar describes the hierarchical structure of the XML tree.

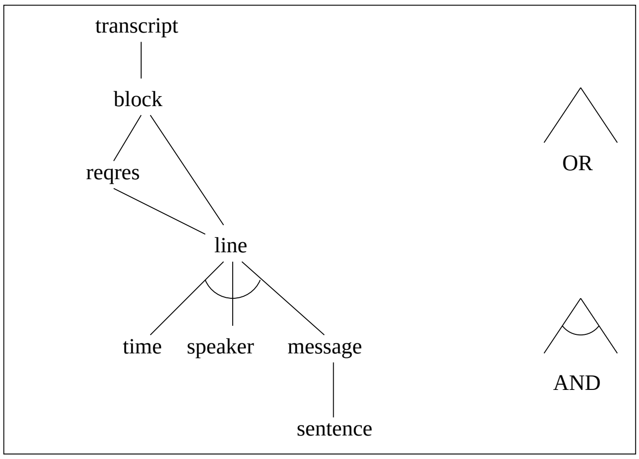
The grammar which is the basis for the tree of our XML structure is derived intuitively from the structure of the original transcripts (see appendices A and B).

The whole *transcript* is comprised of lines. Each of these lines of the transcript contains three parts:

- a consecutive *time code*,
- the person who is the *speaker* (or in some cases a machine sounding a warning tone) and
- the spoken *message* itself.

Sometimes, two or more lines form a *block* because they belong to a common dialog act. The actual message can contain more than one *sentence*, and each of these sentences can have its own *topic*.

Therefore, our XML structure starts with the $< transcript >$. Branching from there are the lines of the original transcript marked with $< line >$, combined into $< block >$. A $< line >$ consists of the three parts $< time >$, $< speaker >$ and $< message >$.



If a sentence contains one or more keywords, these are marked with the $< keyword >$ tag. It has a required attribute, pointing out the keyword's possible contexts it can occur in (see appendix D). The $< sentence >$ tag has a required attribute as well: its sentence type (question, exclamation or statement).

We included a $< topic >$ tag for further extensions: when a sentence covers more than one semantic topic it can be divided into sections.

3.3 Design of the Perl script

Since we are working with transcripts of natural speech and want to markup relations between sentences spoken in the course of the dialog, we have to load the whole transcript into memory at the beginning of the execution of the script. We cannot simply mark it line by line, as we maybe could with some other text. This enables us to jump back to previously processed pieces of the transcript.

Therefore, we internally build an array containing all the lines of the original transcript, with each original line being one element in the array. Each of these list elements then gets analyzed for time and speaker information as well as possible sentence separators. With this new data, the single element gets written back to the original array, but now it is a hash with the keys *time*, *speaker* and *message*, where *message* itself is an array of the separate sentences.

So, the original line

```
11:58:28 F/O Fasten right. Approach checklist complete.
```

becomes a hash with the following pairs of key and values:

time	11:58:28
speaker	F/O
message	1. Fasten right. 2. Approach checklist complete.

For a more insight view, check the annotations made in the perl script itself (see appendix F).

4 Example analyzis

4.1 Original transcript

Below is the first 8 lines of the original ASCII transcript of AA261. The only structure in this format is the use of the tabs between time, speaker and message and the linebreak at the end of each line.

```
16:09:55  ASA261 Center Alaska two sixty one we are uh in a dive here
16:10:01  R30 Alaska two sixty one uh say again
16:10:03  ASA261  (unintelligible) pitch
16:10:01  R30 Alaska two sixty one say again sir
16:10:06  ASA261  Yeah we're out of twenty six thousand feet
                  we're in a vertical dive - not a dive yet -
                  but uh we've lost vertical control of our airplane
16:10:07  R30 Alaska two sixty one roger
16:10:28  ASA261  We're at twenty three seven request uh -
                  yeah we''ve got it back under control there no we don't
                  (unintelligible)
16:10:36  R30 Alaska two sixty one uh say the altitude
              you'd like to uh remain at
```

4.2 XML source

After processing the ASCII transcript, you get the same transcript as before in XML, with added meta information. At first glance, this looks harder to understand than the original. After applying an appropiate style sheet and viewing it with a XML browser, though, it offers much more options in human readability.

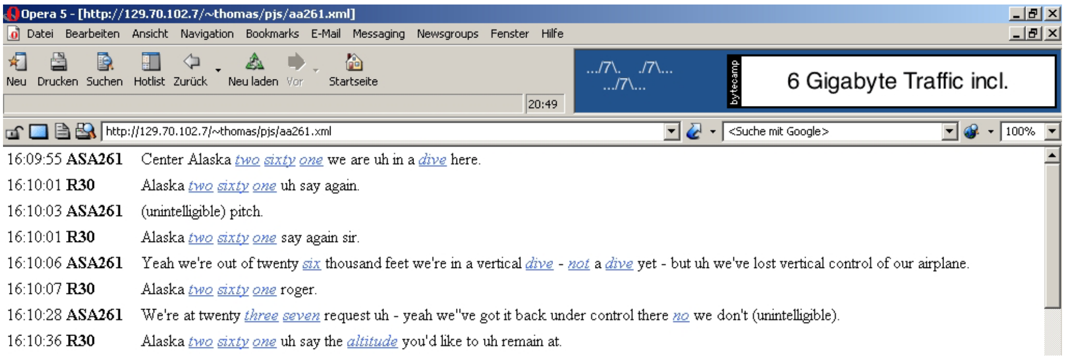
```
<?xml version="1.0'' encoding="iso-8859-1"?>

<transcript>
  <line>
    <time>
      16:09:55
    </time>
    <speaker>
      ASA261
    </speaker>
    <message>
      <sentence type="statement">
        <topic>Center Alaska <keyword context="radioNumeral">two</keyword>
        <keyword context="radioNumeral">sixty</keyword>
        <keyword context="radioNumeral">one</keyword>
        we are uh in a <keyword context="altitudeAbsolute,altitudeChange">
        <keyword context="altitudeChange,altitudeAbsolute">dive</keyword>
        </keyword> here.</topic>
      </sentence>
    </message>
  </line>
```

```
<line>
  <time>
    16:10:01
  </time>
  <speaker>
    R30
  </speaker>
  <message>
    <sentence type="statement">
      <topic>Alaska <keyword context="radioNumeral">two</keyword>
       <keyword context="radioNumeral">sixty</keyword>
       <keyword context="radioNumeral">one</keyword> uh say again.</topic>
    </sentence>
  </message>
</line>
<line>
  <time>
    16:10:03
  </time>
  <speaker>
    ASA261
  </speaker>
  <message>
    <sentence type="statement">
      <topic>(unintelligible) pitch.</topic>
    </sentence>
  </message>
</line>
<line>
  <time>
    16:10:01
  </time>
  <speaker>
    R30
  </speaker>
  <message>
    <sentence type="statement">
      <topic>Alaska <keyword context="radioNumeral">two</keyword>
      <keyword context="radioNumeral">sixty</keyword>
      <keyword context="radioNumeral">one</keyword>
      say again sir.</topic>
    </sentence>
  </message>
</line>
<line>
  <time>
    16:10:06
  </time>
  <speaker>
    ASA261
  </speaker>
  <message>
    <sentence type="statement"><topic>Yeah we’re out of twenty
      <keyword context="radioNumeral">six</keyword> thousand feet
      we’re in a vertical
      <keyword context="altitudeAbsolute,altitudeChange">
      <keyword context="altitudeChange,altitudeAbsolute">dive</keyword>
      </keyword> - <keyword context="communication">not</keyword> a
      <keyword context="altitudeAbsolute,altitudeChange">
      <keyword context="altitudeChange,altitudeAbsolute">dive</keyword>
      </keyword> yet - but uh we’ve lost vertical control
      of our airplane.</topic>
    </sentence>
  </message>
</line>
<line>
  <time>
    16:10:07
  </time>
  <speaker>
    R30
  </speaker>
  <message>
    <sentence type="statement">
      <topic>Alaska <keyword context="radioNumeral">two</keyword>
      <keyword context="radioNumeral">sixty</keyword>
      <keyword context="radioNumeral">one</keyword> roger.</topic>
    </sentence>
  </message>
</line>
<line>
  <time>
    16:10:28
  </time>
  <speaker>
    ASA261
  </speaker>
  <message>
    <sentence type="statement">
      <topic>We’re at twenty <keyword context="radioNumeral">three</keyword>
      <keyword context="radioNumeral">seven</keyword> request uh -
      yeah we’’ve got it back under control there
      <keyword context="communication">no</keyword> we don’t
      (unintelligible).</topic>
    </sentence>
  </message>
</line>
<line>
  <time>
    16:10:36
  </time>
  <speaker>
    R30
  </speaker>
  <message>
    <sentence type="statement">
      <topic>Alaska <keyword context="radioNumeral">two</keyword>
      <keyword context="radioNumeral">sixty</keyword>
      <keyword context="radioNumeral">one</keyword> uh say the
      <keyword context="altitudeAbsolute,altitudeChange">altitude</keyword>
      you’d like to uh remain at.</topic>
    </sentence>
  </message>
</line>
```

4.3 XML-to-screen output

This is a screenshot of the web browser Opera v5.11 displaying the above part of the transcript in the XML version using a rudimentary CSS style sheet.


Opera 5 - [http://129.70.102.7/~thomas/pjs/aa261.xml]
Datei Bearbeiten Ansicht Navigation Bookmarks E-Mail Messaging Newsgroups Fenster Hilfe
Neu Drucken Suchen Hotlist Zurück Neu laden Vor Startseite
20:49
bytecamp
6 Gigabyte Traffic incl.
http://129.70.102.7/~thomas/pjs/aa261.xml
<Suche mit Google>
100%

16:09:55 **ASA261** Center Alaska *two* *sixty* *one* we are uh in a *dive* here.

16:10:01 **R30** Alaska *two* *sixty* *one* uh say again.

16:10:03 **ASA261** (unintelligible) pitch.

16:10:01 **R30** Alaska *two* *sixty* *one* say again sir.

16:10:06 **ASA261** Yeah we're out of twenty *six* thousand feet we're in a vertical *dive* - *not* a *dive* yet - but uh we've lost vertical control of our airplane.

16:10:07 **R30** Alaska *two* *sixty* *one* roger.

16:10:28 **ASA261** We're at twenty *three* *seven* request uh - yeah we''ve got it back under control there *no* we don't (unintelligible).

16:10:36 **R30** Alaska *two* *sixty* *one* uh say the *altitude* you'd like to uh remain at.

4.4 Summary

The markup of the syntactic structure resp. <time>, <speaker>, <message>, <sentence>, <keyword> etc. works correctly for more than 95 per cent of the original lines of the ASCII texts. Especially the marking-up and categorizing of the keywords and sentences is an enormous improvement in working with Cockpit Voice Recordings. Now these transcripts can be searched, parsed and compared automatically. This is important in analyzing the activities in the cockpit and the radio communication between the involved parties.

Our plans for the future are improving the markup of the semantic structures resp. request-response dialog structure. A better style sheet in XSL should ensure a superior visualization of the results. For the perl script, a better user interface is in work.

References

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[2] Martin Ellermann, Mirco Hilbert: Developing an ATC Grammar using the Review of the Cushing Grammar, 2001, RVS, University of Bielefeld, http://www.rvs.uni-bielefeld.de/publications/abstracts.html#ATC-grammar

[3] Keyword list, http://www.geschichte.uni-bielefeld.de/~thomas/pjs/kwlist.txt

[4] The current version of the perl script, http://www.geschichte.uni-bielefeld.de/~thomas/pjs/script.pl

[5] Transcript of AA261 flight, http://www.geschichte.uni-bielefeld.de/~thomas/pjs/aa261.txt

[6] Transcript of CA676 flight, http://www.geschichte.uni-bielefeld.de/~thomas/pjs/china676.txt

[7] Transcript of AirEx827 flight, http://www.geschichte.uni-bielefeld.de/~thomas/pjs/airex827.txt

[8] XML version of the transcript of AirEx827 flight, http://www.geschichte.uni-bielefeld.de/~thomas/pjs/airex827.xml

[9] XML version of the transcript of AA261 flight, http://www.geschichte.uni-bielefeld.de/~thomas/pjs/aa261.xml

[10] The Aviation Safety Network, http://www.aviation-safety.net/

[11] Definition of context free grammars with examples http://www.cs.rochester.edu/users/faculty/nelson/courses/csc_173/grammars/cfg.html

[12] ActiveState Perl software distribution http://aspn.activestate.com/ASPN/Perl/

[13] Definition of the XML standard http://www.w3.org/XML/

Appendix A The grammar behind the XML structure

This context free grammar is derived intuitively from the structure of the original Cockpit Voice Recorders transcripts and is the basis for our XML DTD.

```
G={N, T, R, S}

N={TRANSCRIPT,  BLOCK,  REQRES,  LINE, BREAK,  TIME,  MESSAGE,  SENTENCE,
 KEYWORD,  SPEAKER,  TEXT,  CAPTAIN,  FIRSTOFFICER,  TOWER,  OTHERSPEAKER01,
 OTHERSPEAKER02,  OTHERSPEAKER03,  OTHERSPEAKER04,  LETTERS,  LETTER}

T={ a, b, c, d, e, f, g, h, i, j, k, l, m, n, o, p, q, r, s, t, u, v, w, x,
          y, z, 1, 2, 3, 4, 5, 6, 7, 8, 9, 0, :, ., ,, -}

R={ (TRANSCRIPT::=BLOCK|TRANSCRIPT BLOCK)
         (BLOCK::=REQRES|LINE)
         (REQRES::=LINE|REQRES LINE)
         (LINE::=TIME SPEAKER MESSAGE|BREAK)
         (MESSAGE::=SENTENCE|MESSAGE SENTENCE)
         (SENTENCE::=TOPIC|SENTENCE TOPIC)
         (TOPIC::=KEYWORD|LETTERS|DOTS|KEYWORD SENTENCE|LETTERS SENTENCE|
                  DOTS SENTENCE)
         (SPEAKER::=CAPTAIN|FIRSTOFFICER|TOWER|OTHERSPEAKER01|OTHERSPEAKER02|
                    OTHERSPEAKER03|OTHERSPEAKER04)
    (BREAK::=LETTERS)
    (TEXT::=LETTERS)
    (TIME::=LETTERS)
    (CAPTAIN::=LETTERS)
    (FIRSTOFFICER::=LETTERS)
    (TOWER::=LETTERS)
    (OTHERSPEAKER01::=LETTERS)
    (OTHERSPEAKER02::=LETTERS)
    (OTHERSPEAKER03::=LETTERS)
    (OTHERSPEAKER04::=LETTERS)
    (KEYWORD::=LETTERS)
    (DOTS::=LETTERS)
    (LETTERS::=LETTER|LETTERS LETTER)
    (LETTER::=a|b|c|d|e|f|g|h|i|j|k|l|m|n|o|p|q|r|s|t|u|v|w|x|y|z|
             1|2|3|4|5|6|7|8|9|0|:|.|, |-)
  }

S={TRANSCRIPT}
```

Appendix B   The Document Type Definition (DTD)

This XML DTD is designed on the basis of the context free grammar.

```
<!ELEMENT transcript (block+)>
<!ELEMENT block (reqres|line)>
<!ELEMENT reqres ((line+)|(reqres*))>
<!ELEMENT line ((time, speaker, message)|break)>
<!ELEMENT message (sentence*)>
<!ELEMENT sentence (topic+)>
<!ELEMENT topic (keyword|#PCDATA|dots)+>
<!ELEMENT speaker (captain|firstofficer|tower|
   otherspeaker01|otherspeaker02|otherspeaker03|otherspeaker04)>
<!ELEMENT break #PCDATA>
<!ELEMENT text #PCDATA>
<!ELEMENT time #PCDATA>
<!ELEMENT captain #PCDATA>
<!ELEMENT firstofficer #PCDATA>
<!ELEMENT tower #PCDATA>
<!ELEMENT otherspeaker01 #PCDATA>
<!ELEMENT otherspeaker02 #PCDATA>
<!ELEMENT otherspeaker03 #PCDATA>
<!ELEMENT otherspeaker04 #PCDATA>
<!ELEMENT keyword #PCDATA>
<!ELEMENT dots #PCDATA>

<!ATTLIST sentence type (interrogation|exclamation
   |statement) #REQUIRED "statement">

<!ATTLIST keyword context (C_all|C_altitude|C_absoluteAltitude
   |C_relativeAltitude|C_altitudeChange|C_communication
   |C_radioFrequency|C_radioAlphabet|C_radioNumeral|C_confirmation
   |C_instruction|C_direction|C_north|C_nw|C_nw|C_west|C_south
   |C_sw|C_se|C_east|C_left|C_right|C_up|C_down|C_directionChange
   |C_distance|C_absoluteDistance|C_relativeDistance|C_distanceChange
   |C_flightState|C_taxiing|C_takeoff|C_climb|C_cruise|C_approach
   |C_descend|C_landing|C_emergency|C_urgency|C_goaround|C_heading
   |C_absoluteHeading|C_relativeHeading|C_headingChange|C_measurement
   |C_angleMeasurement|C_altitudeMeasure|C_speedMeasure
   |C_heightMeasure|C_distanceMeasure|C_volumeMeasurement
   |C_timeMeasurement|C_none|C_object|C_flyingObject|C_groundObject
   |C_airport|C_airportObject|C_taxiway|C_runway|C_runwayObject
   |C_tower|C_plane|C_terrain|C_airTrafficControl|C_permission
   |C_cleared|C_notCleared|C_planePart|C_controlableSystem
   |C_staticSystem|C_position|C_absolutePosition|C_relativePosition
   |C_positionChange|C_mark|C_threshold|C_quality|C_speed
   |C_absoluteSpeed|C_relativeSpeed|C_speedChange|C_technical|C_weather
   |C_fog|C_ice|C_rain|C_snow|C_visibility|C_wind|C_windshear|F_taxiing
   |F_takeoff|F_climb|F_cruise|F_approach|F_descend|F_landing|F_goaround
   |F_emergency|F_urgency |F_all|F_none) #REQUIRED "C_all">
```

Appendix C List of keywords

This list of keywords was built intuitively using an iterative algorithm.

- AOA
- above
- affirmative
- airport
- airspeedindicator
- alpha
- altitude
- approach
- approaching
- approved
- autopilot
- baseleg
- below
- block
- boots
- brake pressure
- brake
- bravo
- bugs
- call
- captured
- centerLine
- charlie
- check
- checklist
- circuit
- clearance
- cleared
- climb
- closer
- compressor
- contact
- copy
- course
- crosswind
- decrease
- degrees
- delta
- descend
- descending
- distance
- dive
- down
- east
- eastbound
- echo
- eight
- eighty
- elevator
- emergency
- engine
- field
- fifty
- five
- flaps
- flight level
- fly
- flying
- follow
- forward
- four
- fourty
- Foxtrot
- frequency
- fuel
- gear
- go around
- golf
- heading
- hold
- hotel
- hundred
- hydraulics
- inbound
- igniter
- ignition
- increase
- india
- juliett
- kilo
- knots
- landing
- left
- lima
- lower
- maintain
- mark
- marker
- mayday
- mike
- miles
- minutes
- nine
- ninety
- ninty
- no
- nose
- north
- northbound
- november
- ok
- one
- oscar
- pan
- papa
- power
- proceed
- quebec
- rain
- raining
- rate of decend
- recleared
- reduce
- reducing
- right
- romeo
- roger
- rudder
- runway end
- runway
- seven
- seventy
- shears
- showers
- sierra
- six
- sixty
- south
- southbound
- speed
- speedbrake
- spoilers
- stabilizer
- stand by
- standing by
- start
- takeoff
- tango
- taxiway
- ten
- thirty
- three
- threshold
- throttles
- thousand
- thrust lever
- thrust
- traffic
- trim
- turn
- turning Point
- turning
- twenty
- two
- understood
- uniform
- up
- vector
- victor
- visibility
- weather
- west
- westbound
- whiskey
- wind
- windshears
- windshield wipers
- xray
- yankee
- yaw dampers
- yes
- zero
- zulu

Appendix D Contexts

These contexts were determined together with the authors of [1] by analyzing the list of keywords.

C_all
C_altitude
C_absoluteAltitude
C_relativeAltitude
C_altitudeChange
C_communication
C_radioFrequency
C_radioAlphabet
C_radioNumeral
C_confirmation
C_instruction
C_direction
C_north
C_nw
C_nw
C_west
C_south
C_sw
C_se
C_east
C_left
C_right
C_up
C_down
C_directionChange
C_distance
C_absoluteDistance
C_relativeDistance
C_distanceChange
C_flightState
C_taxiing
C_takeoff
C_climb
C_cruise
C_approach
C_descend
C_landing
C_emergency
C_urgency
C_goaround
C_heading
C_absoluteHeading
C_relativeHeading
C_headingChange
C_measurement
C_angleMeasurement
C_altitudeMeasure
C_speedMeasure
C_heightMeasure
C_distanceMeasure
C_volumeMeasurement
C_timeMeasurement
C_none
C_object
C_flyingObject
C_groundObject
C_airport
C_airportObject
C_taxiway
C_runway
C_runwayObject
C_tower
C_plane
C_terrain
C_airTrafficControl
C_permission
C_cleared
C_notCleared
C_planePart
C_controlableSystem
C_staticSystem
C_position
C_absolutePosition
C_relativePosition
C_positionChange
C_mark
C_threshold
C_quality
C_speed
C_absoluteSpeed
C_relativeSpeed
C_speedChange
C_technical
C_weather
C_fog
C_ice
C_rain
C_snow
C_visibility
C_wind
C_windshear

Appendix E Flight phases

These flight phases were taken from the state machine as described in [1].

```
F_taxiing
F_takeoff
F_climb
F_cruise
F_approach
F_descend
F_landing
F_goaround
F_emergency
F_urgency
F_all
F_none
```

Appendix F Source code of the Perl script

```
#!perl

#BEGIN SUBROUTINES

# this subroutines gets the argument message (type: array of strings)
# elements of message are sentences. each gets split into words (token: whitespaces)
# and is compared with the elements in the keywordarray. if found, then marked up
# and written back into variable.
# finally returns a string containing the whole massage marked with everything.
sub markUpKeywords
{
  my(@sentences) = @_;
  my($sentence, @words, $word, $keyword, $message);

  foreach $sentence (@sentences)
  {
    @words = split(/\b/,$sentence,);

    # marks the keyword with context included as attribute to the keyword tag
    foreach $keyword (keys %kwHoL)
    {
      $sentence = "";
      foreach $word (@words)
      {
        if ($word=~/$keyword/gi)
          {
            @keywordattribsarray = @{$kwHoL{$keyword}};

            foreach $keywordattrib (@keywordattribsarray)
            {
              if ($keywordattribs ne "")
                { $keywordattribs = $keywordattribs.",".$keywordattrib; }
              else
                { $keywordattribs = $keywordattrib; }
            }

            $word = ‘‘<keyword context=\"$keywordattribs\">".$word."<\/keyword>";
            $keywordattribs = "";
          }
          $sentence = $sentence.$word;
      }

    }
    if ($sentence =~/<interrogation \/>/) { $sentence = "<sentence
       type=\"interrogation\"><topic>".$sentence."\?<\/topic><\/sentence>"; }
    elsif ($sentence =~/<exclamation \/>/) { $sentence = "<sentence
       type=\"exclamation\"><topic>’’.$sentence."!<\/topic><\/sentence>"; }
    else { $sentence = "<sentence type=\"statement\"><topic>''.
       $sentence."\.<\/topic><\/sentence>"; }
    $sentence =~s/<interrogation \/>|<exclamation \/>|<statement \/>//g;
    $message = $message.$sentence;
  }
  push @message, $sentence;
  #$message = "<message>".$message."<\/message>";
  return @message;
}


# builds up an hash out of our keywords
sub buildKeywordHash
{
  while(defined($keywordline=<KWIN>))
  {
    chomp($keywordline);
    @hashline = split(/\[/,$keywordline,2);
    $hashline[1] =~s/(\]|\[)//g;
    @contexts = split(/\:/,$hashline[1],);

    $kwHoL{$hashline[0]} = [@contexts];
  }

}

# reading in of command line arguments
sub readCmdLine
{
  foreach $cmdarg (@ARGV)
  {
    if ($cmdarg =~/\A-i/) # input
    {
      $inputfile = $cmdarg;
      $inputfile =~s/\-i//;
    }
    elsif ($cmdarg =~/\A-k/) # keywords
    {
      $keywordfile = $cmdarg;
      $keywordfile =~s/\-k//;
    }
    elsif ($cmdarg =~/\A-o/) # output
    {
      $outputfile = $cmdarg;
      $outputfile =~s/\-o//;
    }
    elsif ($cmdarg =~/\A-h/) # cmd line help
    {
      typeHelp();
      goto END;
    }
  }
  if ($inputfile eq "")
  {
    print "\nNo inputfile specified\.\nTerminating\.\.\.\n\nUse \-h for help\.\n";
    goto END;
  }
}

# reading in of the file config.cfg for global configuration
sub readConfig
{
  open(CFGIN, "<config.cfg");
  while(defined($configinput=<CFGIN>))
  {
    chomp($configinput);

    # determines which file to write to (just rename input to .xml or
    # specified on command line)
    if ($configinput =~/generate_output_filename\: yes/gi)
    {
      if ($outputfile eq "")
      {
        $outputfile = $inputfile;
        $outputfile =~s/\.txt/\.xml/i;
      }
    }
    elsif ($configinput =~/keyword_file\:/gi)
    {
      $keywordfile = $configinput;
      $keywordfile =~s/keyword_file: //gi;
    }
    # determines the path to the style sheet
    elsif ($configinput =~/stylesheet_path\:/gi)
    {
      $stylesheet = $configinput;
      $stylesheet =~s/stylesheet_path\: //gi;
    }
  }


  close(CFGIN);
}


# checks whether the variables are set
sub variableCheck
{
  if ($keywordfile eq "")
  {
    print "\nNo keywordfile specified\.\nTerminating\.\.\.\n\nUse \-h for help\.\n";
    goto END;
  }
  elsif ($outputfile eq "")
  {
    print "\nNo outputfile specified\.\nTerminating\.\.\.\n\nUse \-h for help\.\n";
    goto END;
  }
  elsif ($stylesheet eq "")
    { $stylesheet = "transcript\.css"}
}


# prints the help to the console
sub typeHelp
{
  print "\n";
  print "Available options\/switches:\n";
  print "‘\-i\: specifies input filename\n";
  print "\-o\: specifies output filename\n";
  print "\-k\: specifies keyword list filename\n";
  print "\n";
  print "Do not put blanks between switch and filename\!";
}


# SCRIPT BODY

# FILEHANDLES
$keywordfile = "";
$inputfile = "";
$outputfile = "";
@transcript;

readCmdLine();
readConfig();

variableCheck();

open(KWIN, "<".$keywordfile); # open handle to keyword list
open(OUT, ">".$outputfile); # open handle to output file
open(IN, "<".$inputfile); # open handle to input ascii transcript

@transcript_in = <IN>;
@transcript_out;

foreach $line (@transcript_in)
{
  chomp ($line);
  $line =˜s/\.\.+/<dots \/>/g; # replaces dots with a tag
  # create 3 strings out of line
  ($time, $speaker, $messagestring) = split(/\t/,$line,3);
  $time = "<time>".$time."<\/time>";
  $speaker = "<speaker>".$speaker."<\/speaker>";

  # add a tag to the punctuation
  $messagestring =~s/\?/<interrogation \/>\?/g;
  $messagestring =~s/!/<exclamation \/>!/g;
  $messagestring =~s/\./<statement \/>\./g;

  # splits the message into the single sentences
  @sentencearray = split(/\?|!|\.|\?\z|!\z|\.\z/,$messagestring);

  @temp = markUpKeywords(@sentencearray);

  push @transcript_out, { %zeile };
}

for $i ( 0 .. $#transcript_out )
{
  print OUT $transcript_out[$i]{time};
  print OUT $transcript_out[$i]{speaker};
  print OUT "<message>";

  foreach $element ( @{$transcript_out[$i]{message}} )
  {
    print OUT $element;
  }
  print OUT "<\/message>";
  print OUT "\n";
}

END:
# nothing
```