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RESULTS OBTAINED WITH A NEW METHOD
FOR THE AUTOMATIC ANALYSIS OF
SENTENCE STRUCTURES

We present in this paper a method for the automatic analysis of sentence structures.

Our purpose is to constitute a frequency dictionary of the different structures used in the language. This dictionary will enable us to select the most useful sentence structures in order to recommend their exclusive use for the writing of texts intended for automatic translation.

We think that the automatic translation will be possible only if the texts are submitted to rules which limit the complexity of their syntax. These limitations will be the less noticed by an author as only the most unusual structures would have been left out. Of course the number of permitted structures will increase as the automatic translation codes are improved.

The sentence structures are obtained by a statistical analysis of the word strings according to procedures developed in the information theory.

In the present paper we have analysed only groups of two consecutive words as an example of our method.

The same type of analysis can be generalized by considering non-consecutive words and groups of more than two words.

1. GROUPS

The first step of the analysis is to put the words into groups according to their grammatical properties, for example: noun, adjective, article and so on. The number of groups has been limited to keep significative frequencies with respect to the length of the corpus (3500 words). In the text under study, we have used 67 groups. A list of these groups is given in Table 3.

Of course, our classification is somewhat arbitrary as it is based on a preliminary knowledge of the language. We will show later how the results of the analysis can help us to detect inadequate classifications.

Each word of the corpus has been replaced by a symbol (two figures integer) representing its grammatical group. We consider the words inside the sentence, that is to say between two strong punctuation signs (. ; ! ?). Inside the sentence all punctuation signs are suppressed.

We will call now "words" these symbols.

2. DICTIONARY OF STRINGS

The second step is the constitution of a string dictionary.

A sentence containing N words produces $(N-1)$ strings. For instance, the sentence *Her daughter gave me an Italian lesson every day* represented by the string "55 04 01 44 45 05 04 85 04", produces the following strings:

156	55	HER	**
2.173	1		***
157	4	DAUGHTER	** *
0.024	2		*****
158	1	GAVE	** * *
1.267	1		*** *
159	44	ME	** *
-0.702	4		**
160	45	AN	** *
2.379	1		*** *
161	5	ITALIAN	** * *
1.860	2		*** *
162	4	LESSON	**** * *
-0.421	3		***
163	85	EVERY	** *
2.194	1		*****
164	4	DAY	**
First (complete) string	55 04 01 44 45 05 04 85 04		
Second string	04 01 44 45 05 04 85 04		
etc....	01 44 45 05 04 85 04		
	44 45 05 04 85 04		
	45 05 04 85 04		
	05 04 85 04		
	04 85 04		
Last string	85 04		

Each string is obtained by suppressing the first word of the preceding string.

The dictionary emphasizes the identical strings *whatever their position* in the sentence might be. A sample of the dictionary is given in Table 1.

For example, the string 05 04 which means an adjective followed by a common noun at the end of a sentence has the rank number 244, occurs 9 times in the sentences number 9, 10, 35 and so on.

All the strings beginning by the groups 05, 04 are also listed.

3. SENTENCE STRUCTURE

The last step of the analysis is the production of sentence structures, using the correlations between two consecutive words.

We can compare the probability P_j of a word j in the corpus and the conditional probability P_j (if i) of the same word when the preceding word is given equal to i . We shall call in this paper "degree of correlation" the logarithm of the ratio of the conditional probability and the probability:

$$C_{ij} = \text{Log}_2 P_j (\text{if } i) / P_j$$

The degree of correlation will be positive when the probability to get a word is increased by the knowledge of the preceding word, and negative when this probability is decreased. It is a measure of the "affinity" of two consecutive words.

This procedure can be generalized by considering groups of more than two words, not necessarily consecutive.

For each sentence of the corpus we can build a structure based on the correlation between two consecutive words in the following way. Inside the sentence, consecutive words are connected two by two in order of decreasing degree of correlation. For instance in the sentence:

She loved a good laugh

we have the following degrees of correlation:

<i>She loved</i>	= 2.56
<i>loved a</i>	= 1.23
<i>a good</i>	= 2.38
<i>good laugh</i>	= 1.86

Therefore the first words to be connected are *She* and *loved* then *a* and *good*. We will consider that their union is the first level. Then the word *laugh* will be connected to the group *a good*. This union will be a second level and finally the two halves of the sentence are connected and this union will be the third level.

This structure can be represented by the following graph, automatically produced by the computer, and by the string 1 3 1 2 obtained by writing the sequence of the successive levels.

SENTENCE NO 9

231		44	SHE	**	
	2.564	1		*****	
232		1	LOVED	**	*
	1.232	3			**
233		45	A	**	*
	2.379	1		***	*
234		5	GOOD	**	**
	1.860	2		***	
235		4	LAUGH	****	

Degrees of correlation:

<i>She loved</i>		2.56
<i>loved a</i>		1.23
<i>a good</i>		2.38
<i>good laugh</i>		1.86

String of groups: 44 01 45 05 04
 String of levels: 1 3 1 2

4. DICTIONARY OF STRUCTURES

This procedure has been applied for all the sentences of the text, producing strings of numbers which represent the structure of these sentences.

For each string of numbers, by suppressing the highest number we obtain 2 strings representing 2 substructures of this sentence. We carry on this procedure till the string has only 1 number, that is to say represents the structure of a group of 2 words.

For instance the structure of the sentence *Her daughter gave me an Italian lesson every day* is represented by the following string of numbers:

SENTENCE NO 5

156	55	HER	**
2.173	1		***
157	4	DAUGHTER	** *
0.024	2		*****
158	1	GAVE	** * *
1.267	1		*** *
159	44	ME	** *
-0.702	4		**
160	45	AN	** *
2.379	1		*** *
161	5	ITALIAN	** * *
1.860	2		*** *
162	4	LESSON	**** *
-0.421	3		***
163	85	EVERY	** *
2.194	1		*****
164	4	DAY	**

Complete string: 1 2 1 4 1 2 3 1 (level 4)
 1 substring : 1 2 3 1 (level 3)
 2 substrings: 1 2 1 1 2 (level 2)
 3 substrings: 1 1 1 1 (level 1)

All the structures and substructures are classified in a dictionary, giving their frequencies and the positions of the sentences containing the corresponding word strings (Table 2).

For example, the structure 1 4 2 1 3 has the rank number 65 and is found 5 times in the sentences number 12 16 21 24 41.

5. CLASSIFICATION ERRORS

If the structure of a sentence is unsatisfactory, this can be due to an error in the classification of a word of this sentence. This observation is used to detect and correct classification errors. For example in the sentence:

<i>But</i>	<i>I</i>	<i>like</i>	<i>to</i>	<i>come</i>	<i>mother</i>
81	44	01	17	22	24

```

graph LR
    I[44] --- like[01]
    to[17] --- come[22]
    Ilike[I like] --- tocome[to come]
    But[81] --- Ilike_tocome[I like to come]
    Ilike_tocome --- mother[24]
  
```

$$C = \sum_{ij} P_{ij} C_{ij}$$

In order to check the validity of the choice of the grammatical group for a word, the quantity of information associated to the law of succession of the groups is measured. Then, changing the choice of the group, the quantity of information is measured again for this new classification. The greater the quantity of information associated to a law of succession of the groups, the better the distribution of these words into these groups.

6. CONCLUSION

This shows that the correlation of 2 consecutive words, although insufficient, will play an important part in the more elaborated methods of analysis that we are now developing.

[illegible]

TABLE 2.

<i>Rank</i>	<i>Frequency</i>	
56	1	0 1 3 2 1 4 5 1 2 1 6 1 2 3 1 22
57	1	0 1 3 2 1 6 4 3 1 2 5 1 3 2 1 61
58	1	0 1 4 1 2 1 3 33 sentence number
59	1	0 1 4 1 2 1 3 1 2 48
60	1	0 1 4 1 2 1 3 5 1 33
61	1	0 1 4 1 2 1 3 5 1 6 3 1 2 4 33
62	1	0 1 4 1 2 3 15
63	1	0 1 4 1 2 3 1 63
64	1	0 1 4 1 2 3 5 1 2 3 4 2 1 3 1 15
65	5	0 1 4 2 1 3 12 16 21 24 41
66	2	0 1 4 3 1 2 20 42
67	1	0 1 4 3 1 2 5 1 2 20
68	1	0 1 5 1 2 1 3 2 1 4 18
69	1	0 1 5 1 2 1 3 2 1 4 6 18
70	1	0 1 5 1 2 1 3 2 1 4 6 7 1 18
71	1	0 1 5 1 4 2 1 3 24
72	1	0 1 5 1 4 2 1 3 6 1 2 3 4 24
73	1	0 1 5 2 1 3 4 28
74	1	0 1 5 2 1 3 4 6 1 28
75	1	0 1 6 1 2 5 4 3 1 2 52
76	1	0 1 6 1 2 5 4 3 1 2 7 1

SENTENCE NO 60

3348		65	THOSE	**
	1.421	1		*****
3349		4	THINGS	** *
	0.268	3		**
3350		3	ARE	** *
	1.873	1		*** *
3351		36	NOT	** * *
	1.804	2		***
3352		31	DONE	****

SENTENCE NO 56

3255		29	WHAT	**
	4.345	1		***
3256		3	IS	** *
	1.121	2		***
3257		5	WRONG	**** *
	-0.095	3		**
3258		27	WITH	**** *
	2.026	2		***
3259		55	HIS	** *
	2.173	1		***
3260		4	MORALS	**

SENTENCE NO 58

3323		54	THAT	**
	2.306	1		***
3324		2	SOUNDS	** *
	1.570	2		***
3325		66	QUITE	** * *
	2.689	1		*** *
3326		5	IMPOSSIBLE	** *
	-2.392	3		**
3327		1	CRIED	** *
	1.663	1		*****
3328		24	KITTY	**

SENTENCE NO 36

1839		44
	2.564	1
1840		1
	1.859	2
1841		55
	2.173	1
1842		4
	1.012	3
1843		7
	1.180	2
1844		45
	1.573	1
1845		4

SHE **

 FORCED ** *

 HER ** * *
 *** *
 LIPS ** *
 **
 INTO **** *

 A ** *

 SMILE **

SENTENCE NO 20

1121		35
	2.114	1
1122		4
	0.024	4
1123		1
	0.273	3
1124		7
	2.460	1
1125		55
	2.173	2
1126		4
	-1.604	5
1127		35
	3.863	1
1128		25
	2.087	2
1129		4

THE **

 MOTHER ** *

 GAVE ***** * *
 *** *
 INTO ** * *
 *** * *
 HER ** * * *
 *** *
 CARE ***** *
 **
 THE ** *
 *** *
 SMALLER ** * *

 CHILDREN ****

SENTENCE NO 19

1079		24	KITTY	**
	1.644	1		***
1080		1	FOUND	** *
	0.926	2		*****
1081		35	THE	** * *
	2.114	1		*** *
1082		4	WORK	** *
	-1.198	4		**
1083		45	A	** *
	1.573	1		***** *
1084		4	REFRESHMENT	** * *
	0.221	3		***
1085		87	TO	** *
	2.511	1		*** *
1086		55	HER	** * *
	2.173	2		***
1087		4	SPIRIT	****

SENTENCE NO 49

2820		44	SHE	**
	2.564	1		*****
2821		1	HAD	** *
	0.273	3		***
2822		7	AMONG	** * *
	2.460	1		*** * *
2823		55	HER	** * * *
	2.173	2		*** *
2824		4	ANCESTORS	**** *
	-5.241	4		**
2825		4	PERSONS	** *
	1.012	1		*** *
2826		7	OF	** * *
	-0.801	2		*****
2827		5	HISTORIC	** *
	1.860	1		***
2828		4	IMPORTANCE	**

SENTENCE NO 50

2830		94
	2.047	4
2831		68
	5.493	2
2832		28
	7.456	1
2833		33
	2.742	3
2834		5
	0.490	5
2835		17
	4.406	1
2836		21
	0.540	3
2837		66
	0.870	2
2838		85
	2.194	1
2839		4

IT	*****

MUST	**** *
	*** *
HAVE	** * *
	*** *
BEEN	** * *

HARD	***** *
	**
TO	** *
	***** *
LEAVE	** * *

SO	**** *

MUCH	** *

GRANDEUR	**

SENTENCE NO 52

2850		44
	2.564	1
2851		1
	0.926	6
2852		35
	3.863	1
2853		25
	2.087	2
2854		4
	1.192	5
2855		9
	2.438	4
2856		44
	2.727	3
2857		8
	3.709	1
2858		46
	2.804	2
2859		31
	-0.655	7
2860		1
	1.663	1
2861		24

SHE	**

HAS	** *

THE	** *
	*** *
MOSTBEAUTIFUL	** * *
	***** *
HANDS	**** * *
	*** *
THAT	***** *
	*** *
I	***** *
	*** *
HAVE	** * *
	*** *
EVER	** * *
	*** *
SEEN	**** *
	**
SAID	** *

KITTY	**

SENTENCE NO 55

3216		80	BUT	**	
	2.061	1		***	
3217		46	SOMETIMES	** *	
	0.265	2		*****	
3218		24	SISTERJOSEPH	** *	*
	3.245	1		***	*
3219		2	THOUGHT	**	*
	-0.934	5			**
3220		44	HE	**	*
	2.564	1		***	*
3221		1	SPOKE	** *	*
	1.125	2		***	*
3222		6	BADLY	** *	*
	2.227	1		***	*
3223		56	ONPURPOSE	** *	*
	0.505	3		***	*
3224		17	TO	** *	*
	4.406	1		***	*
3225		21	MAEK	** *	*
	1.036	2		***	*
3226		44	YOU	****	*
	0.302	4		***	
3227		22	LAUGH	*****	

SENTENCE NO 32

1734		7
	2.122	1
1735		35
	2.114	2
1736		4
	2.288	1
1737		97
	0.113	3
1738		4
	0.085	4
1739		44
	2.115	1
1740		3
	1.047	3
1741		7
	2.122	1
1742		35
	2.114	2
1743		4
	-1.074	5
1744		66
	1.696	3
1745		49
	2.983	1
1746		44
	2.212	2
1747		2

BY	**

THE	** *

MERCY	** * *
	*** *
OF	** *

PROVIDENCE	***** *

I	** * *
	***** *
WAS	** * * *
	*** *
AT	** * *
	*** *
THE	** * *
	*** *
DOOR	**** *
	**
JUST	***** *

AS	** *
	*** *
SHE	** * *

CAME	****

SENTENCE NO 14

728		94	IT	**	
	3.529	1		***	
729		3	WAS	** *	
	1.873	2		***	
730		36	NOT	**** *	
	1.760	3		***	
731		49	TILL	** * *	
	2.983	1		*** * *	
732		44	I	** * * *	
	2.564	2		*** *	
733		1	MADE	**** *	
	1.232	4		***	
734		45	A	** * *	
	2.379	1		*** * *	
735		5	LONG	** * *	
	1.860	2		*** * *	
736		4	JOURNEY	**** * *	
	1.777	3		*** *	
737		16	IN	** * *	
	2.637	1		***** *	
738		24	CHINA	** *	
	0.075	5		**	
739		9	THAT	**** *	
	2.438	2		*** *	
740		44	I	** * * *	
	2.564	1		*** * *	
741		1	FOUND	** * *	
	1.710	3		*****	
742		54	THIS	*****	

SENTENCE NO 15

792		35	THE	**
	2.114	1		*****
793		4	MOMENT	** *
	0.085	4		***
794		44	YOU	** * *
	2.564	1		*** *
795		1	THINK	** * *
	1.447	2		*** *
796		26	OF	*** * *
	0.329	3		*** *
797		44	HIM	***** *
	-3.667	5		**
798		44	YOU	** *
	2.564	1		*** *
799		1	THINK	** * *
	1.447	2		*** *
800		26	OF	*** * *
	0.329	3		*** *
801		44	HIM	***** * *
	-2.311	4		***
802		16	IN	*** *
	1.721	2		*** *
803		85	SOME	** * * *
	2.194	1		*** *
804		4	SITUATION	** * *
	1.379	3		***
805		41	DOING	** *
	5.094	1		*****
806		89	SOMETHING	**

SENTENCE NO 22

1536		44	SHE	**	
	2.564	1		*****	
1537		1	FELT	**	*
	1.430	3			***
1538		9	THAT	****	* *
	2.438	2			*** *
1539		44	THEY	**	* *
	2.564	1		***	*
1540		1	LIKED	**	*
	1.267	4			***
1541		44	HER	*****	*
	-0.843	5			***
1542		80	AND	**	* *
	0.124	1		***	* *
1543		31	FLATTERED	**	* *
	-0.240	2		*****	*
1544		80	AND	**	*
	-0.175	1		***	*
1545		5	PROUD	**	*
	-1.993	6			**
1546		44	SHE	**	*
	2.564	1		***	*
1547		1	LIKED	**	*
	1.267	2		***	*
1548		44	THEM	****	*
	-1.076	3		*****	
1549		7	IN	**	*
	-0.345	1		*****	
1550		4	RETURN	**	

TABLE 3.

Group

01	INDICATIVE (TRANSITIVE VERBS)
21	INFINITIVE (TRANSITIVE VERBS)
31	PAST PARTICIPLE (TRANSITIVE VERBS)
41	PRESENT PARTICIPLE (TRANSITIVE VERBS)
51	GERUND (TRANSITIVE VERBS)
02	INDICATIVE (INTRANSITIVE VERBS)
22	INFINITIVE (INTRANSITIVE VERBS)
32	PAST PARTICIPLE (INTRANSITIVE VERBS)
42	PRESENT PARTICIPLE (INTRANSITIVE VERBS)
52	GERUND (INTRANSITIVE VERBS)
03	INDICATIVE (STATE VERBS)
23	INFINITIVE (STATE VERBS)
33	PAST PARTICIPLE (STATE VERBS)
43	PRESENT PARTICIPLE (STATE VERBS)
53	GERUND (STATE VERBS)
08	INDICATIVE (AUXILIARY VERBS)
28	INFINITIVE (AUXILIARY VERB)
68	WOULD, SHOULD, WILL, CAN, MAY, HAVE TO
78	INDICATIVE (TO DO, AUXILIARY VERB)
88	INFINITIVE (TO DO, AUXILIARY VERB)
04	COMMON NOUN
14	COMMON NOUN (POSSESSIVE CASE)
24	PROPER NOUN
34	PROPER NOUN (POSSESSIVE CASE)
44	PRONOUN (PERSONAL)
54	PRONOUN (DEMONSTRATIVE)
64	PRONOUN (INDEFINITE)
74	PRONOUN (PERSONAL REFLEXIVE)
94	PRONOUN (IMPERSONAL)
05	ADJECTIVE (QUALIFICATIVE)
15	ADJECTIVE (COMPARATIVE)
25	ADJECTIVE (SUPERLATIVE)
35	ARTICLE (DEFINITE)
45	ARTICLE (INDEFINITE)
55	ADJECTIVE (POSSESSIVE)
65	ADJECTIVE (DEMONSTRATIVE)
85	ADJECTIVE (INDEFINITE)
95	ADJECTIVE (CARDINAL)
72	ADJECTIVE (PRESENT PARTICIPLE)
73	ADJECTIVE (PAST PARTICIPLE)
93	ADJECTIVE (ORDINAL)
39	ADJECTIVE (INTERROGATIVE)

06 ADVERBS MADE FROM ADJECTIVES
16 ADVERB (PLACE)
26 POSTPOSITION
36 NOT
46 ADVERB (TIME)
56 ADVERB (MANNER)
66 ADVERB (QUANTITY)
76 AS, LIKE
86 ADVERB (REPETITION)
96 ADVERB (EXCLAMATIVE)

07 PREPOSITION
17 TO (INFINITIVE)
27 WITH, WITHOUT
87 TO
97 OF
89 NOTHING, SOMETHING
09 THAT
19 PRONOUN (RELATIVE)
29 PRONOUN (INTERROGATIVE)
49 CONJUNCTION (TIME)
59 CONJUNCTION (CAUSE)
69 CONJUNCTION (SUPPOSITION)
79 CONJUNCTION (COMPARISON)

80 AND
81 BUT, OR
/*