Semantic Modelling for Speech Recognition

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Word-Topic Matrix

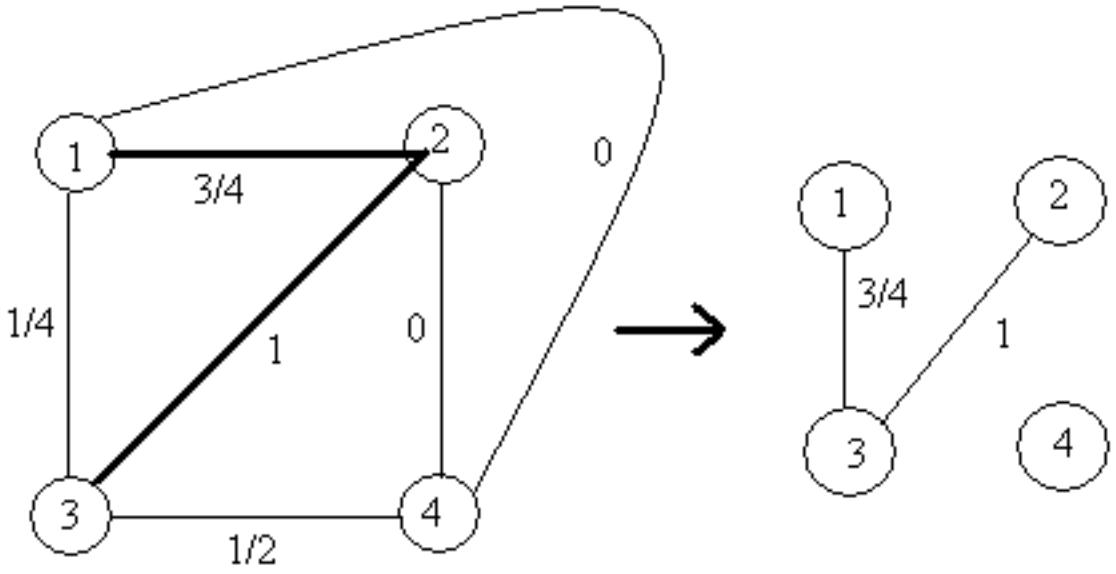
$$\mathbf{S} = [s_{ik}]$$

$$d_{ij} = \sum_{k=1}^{K} s_{ik} s_{jk}.$$

$$d'_{ij} = d_{ij} / \max_{i<j} \{d_{ij}\}. \qquad 0 \leq d'_{ij} \leq 1.$$

Graph with Topic Simmilarities

$$p_{ij} = \prod_{(a,b)\in P(i,j)} d'_{ab},$$



Including Semantic Relations in Word - Topic Matrix

$$S' = [s'_{ik}].$$

$$s'_{ik} = s_{ik} + \alpha^{-1} \sum_{j \in N} p_{ij} s_{jk}.$$

Process of Finding Most Similar Topics

1. Find n single edge paths with the highest measures d'_{ij}.
2. Check if the two edges path $P(i, m)$ starting from the node i with the highest measure d'_{ij}, which was found in the step above and going through j to any other edge m, has a better measure p_{im} than the lowest of the n solutions found in the step above. If it does than replace it with m in the list of n similar topics.
3. Conduct the step above for all other single node paths from the list apart from the lowest, nth element.
4. If there are any non single edge paths $P(i, j)$ on the list on position different then nth, reapeat a process similar to step 2. Check if after adding any other edge a measure of path p_{ij} is higher than a measure of the nth position. Than replace the previous path with a new longer one path with higher p_{ij}.

Proof that the Process is Exhaustive

$$d'_{in_1} > d'_{ij} \quad \forall n_1 \in N_1, \forall j \notin N_1$$
$$d'_{il} > d'_{in_1} \quad \forall n_1 \in N_1.$$

$$0 \leq d'_{ij} \leq 1 \quad \forall i, j \in \{1, \ldots, I\}$$

$$d'_{in_1} d'_{n_1 j} \leq d'_{in_1} \quad \forall j \in N_2.$$

i – the analysed topic

N1 – the set found in the first step

l – the element with lowest measure of N1

$N_2 = T/(\{i_a\} \bigcup N_1)$

$$d'_{il} \leq d'_{ij} \quad \forall j \in N_2$$

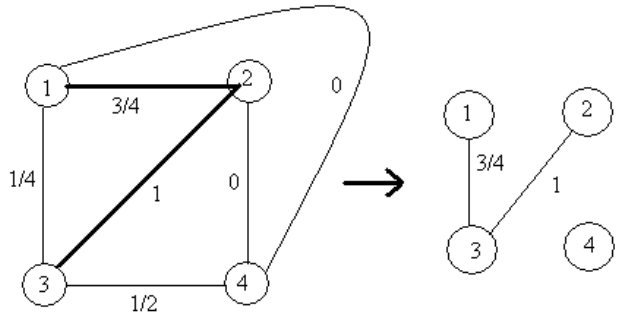
$$d'_{in_1} d'_{n_1 j} \leq d'_{il} \quad \forall j \in N_2.$$

$$d'_{in_1} d'_{n_1 j} \leq d'_{ij} \quad \forall j \in N_2.$$

Example

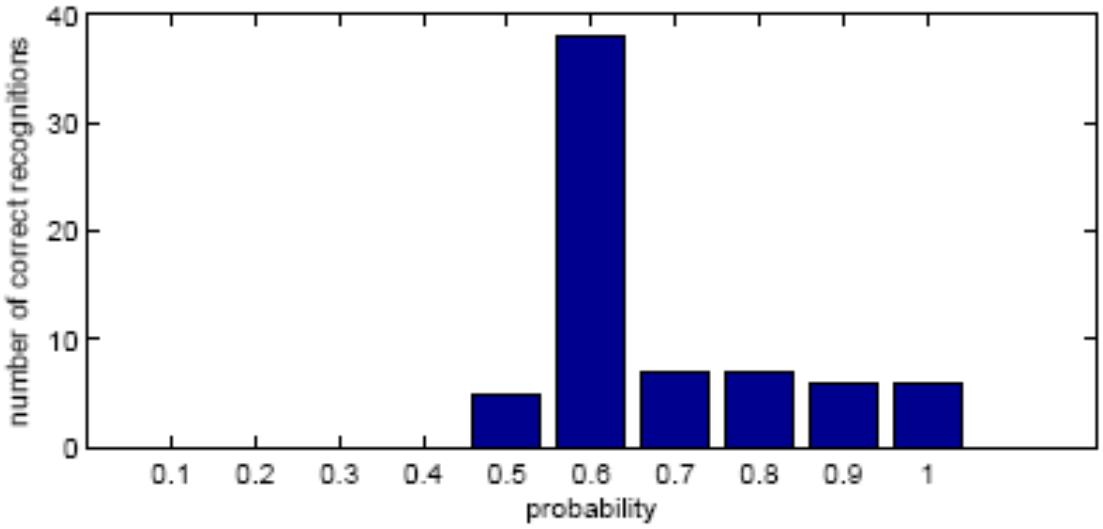
Big John has a house. Big John has a black, aggressive cat. The black aggressive cat has a small mouse. The small mouse is a mammal.

topic	big	John	has	house	black	aggr.	cat	small	mouse	is	mammal
1	1	1	1	1	0	0	0	0	0	0	0
2	1	1	1	0	1	1	1	0	0	0	0
3	0	0	1	0	1	1	1	1	1	0	0
4	0	0	0	0	0	0	0	1	1	1	1
3'	7/8	7/8	15/8	1/2	11/8	11/8	11/8	1	1	0	0

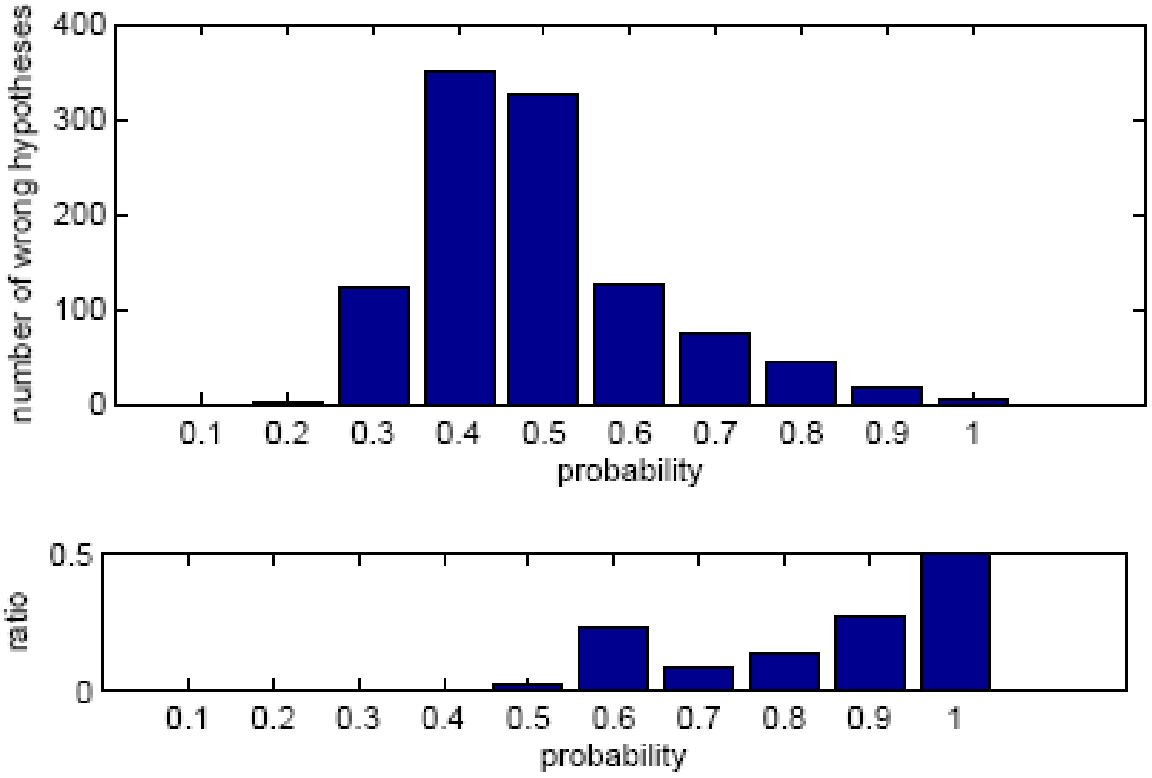


1	2	3	4
4	3	1	0
3	6	4	0
1	4	6	2
0	0	2	4

Histogram of probabilities received from semantic model for hypotheses which are correct recognitions



Histogram of probabilities received from semantic model for hypotheses which are wrong recognitions



Recognition Using Semantic Model

$$P_{sem} = \max_i \sum_{k \in W} s'_{ik}. \qquad P_{sem} \in \Re^+$$

$$p = p_{htk}^{w} p_{sem}.$$

Experimental Results

n	α	w	recognised sentences	%
LSA		25	41	0.36
HTK			33	0.29
3	1	50	48	0.42
3	2	50	46	0.40
3	3	50	46	0.40
7	1	50	35	0.31
7	3	50	45	0.39
7	5	50	46	0.40
5	1	20	44	0.39
5	2	20	55	0.48
5	3	20	60	0.53
5	4	20	59	0.52
5	5	20	59	0.52
3	2	20	61	0.53
3	1	20	50	0.44
7	6	20	59	0.52
7	5	20	61	0.53
7	4	20	59	0.52
8	4	20	57	0.5
8	5	20	61	0.53
8	6	20	60	0.53
9	1	20	28	0.25
9	3	20	49	0.43
9	5	20	57	0.5
9	6	20	61	0.53
9	7	20	59	0.52
11	5	20	54	0.47
11	7	20	60	0.53
11	8	20	60	0.53
11	9	20	58	0.51
9	6	10	58	0.51
9	6	15	60	0.53
9	6	17	60	0.53
9	6	18	61	0.53
9	6	19	61	0.53
9	6	20	61	0.53
9	6	22	59	0.52
9	6	25	58	0.51