Temporal Knowledge Acquisition From Multiple Experts

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Abstract

The paper deals with the research in the area of knowledge acquisition from multiple experts when knowledge includes temporal component. The expert's ranking refinement technique is presented which is based on of the most supported opinion among all the experts. Paper answers to the following questions: how to derive the most supported knowledge from the multiple experts about the unknown temporal relation between the two events; how to make quality evaluation of the most supported opinion; how to make syntactical analysis of the most supported opinion to make necessary corrections; how to make, evaluate, use and refine ranking of all the experts to improve the results.

1. Introduction

The area of knowledge management includes the problem of eliciting expertise from more than one expert. The significance of this subject deals with fast development of telecommunications, Internet, WWW that connects people together and gives possibilities to collect knowledge from different sources. The problems, how to collect different opinions, handle inconsistent and incomplete knowledge taken from them, find consensus, support interface between individual and collective knowledge, are now under great interest of international research.

Could the overlapping knowledge from multiple sources be described in such a way that it is context or even process independent? In [11], the negative answer was given. If more than one expert is used, one must either select the opinion of the best expert or pool the experts' judgements [11, 5]. It is assumed that when experts' judgements are pooled, collectively they offer sufficient cues to lead to the building of a comprehensive theory.

In practice, one of the following three strategies may be used for knowledge acquisition: use the opinion of only one expert; collect the opinions of multiple experts, but use them one at a time, or integrate these opinions. Research described in [7] deals mainly with the strategy of integrating opinions. There it is assumed that acquired knowledge has more validity if it forms a consensus (if such exists) among the experts. In [6], five techniques are discussed and compared for aggregating expertise. In this study, elicited knowledge is aggregated using classical statistical methods (regression and discriminant analysis), the ID3 pattern classification method, the k-NN (Nearest Neighbour) technique, and neural networks. In aggregating knowledge, the authors seek to identify the significance of each of the factors extracted and the functional inter-relationship among the relevant factors.

A logic for reasoning with inconsistent knowledge has been described in [9]. This logic suits reasoning with knowledge coming from different and not fully reliable knowledge sources. Inconsistency may be resolved by considering the reliability of the knowledge sources used. The reliability relation can be interpreted as denoting that if two premisses are involved in a conflict the least reliable premiss has the highest probability of being wrong.

The present paper deals with the integrating multiple experts opinions that include temporal relations between some events. The representation and reasoning about temporal relations are essential for knowledge representation [12], natural language understanding [3,10], planning [2,4], technical diagnosis [8], and other areas. An algebra with binary relations on intervals was introduced by Allen [1]. He gives an algorithm for computing an approximation to the strongest implied relation for each pair of intervals. We use Allen's representation of temporal relations to introduce a technique to manage knowledge obtained from multiple knowledge sources.

The scheme with problems, discussed in this paper, is shown in Figure 1. We consider knowledge that includes multiple experts description of some domain events by defining temporal relationships between them.

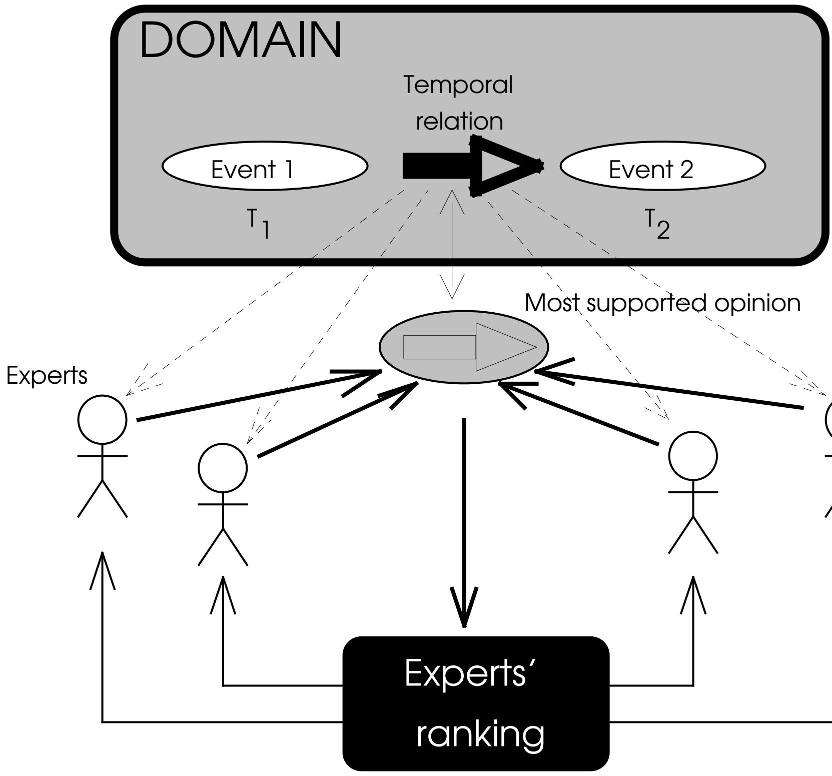


Figure 1. The problem of knowledge acquisition from multiple experts

These problems are:

1. How to derive the most supported knowledge from the multiple experts about the unknown temporal relation between the two events?
2. How to make quality evaluation of the most supported opinion?
3. How to make syntactical analysis of the most supported opinion to make necessary corrections?
4. How to make, evaluate, use and refine ranks of all the experts to improve the results?

2. Basic Concepts

In this chapter, we define main concepts used throughout the paper. We define knowledge about temporal domain as fifth <*S,M,R,T,P*>. The concepts used are the following:

S - the set of *n* knowledge sources or experts;

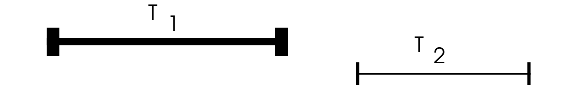
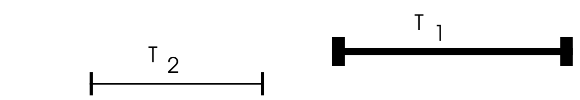
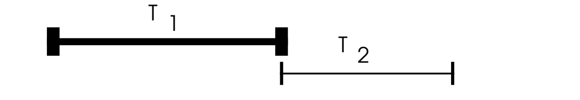
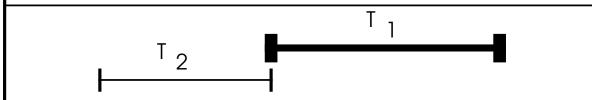
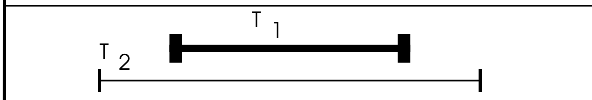
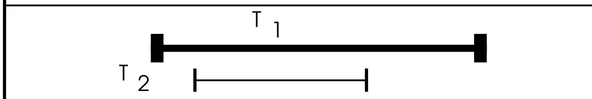
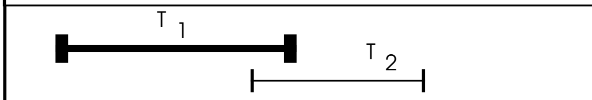
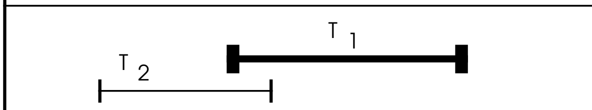
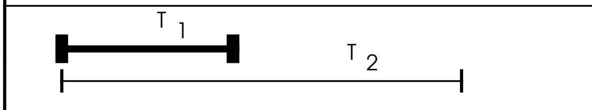
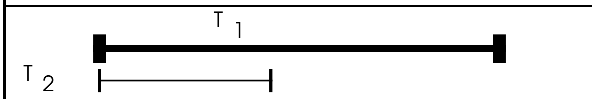
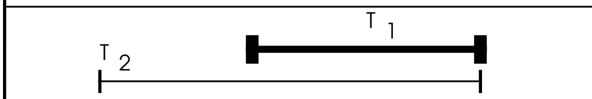
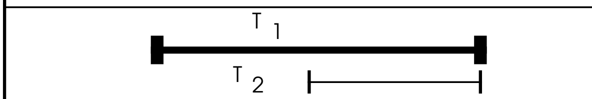
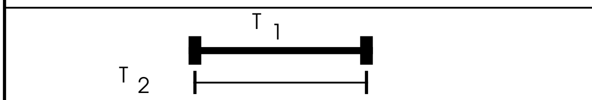
M - the set of *m* basic relations for temporal points (Table 1). In this Table, X^- and X^+ are endpoints of the temporal interval T_1; Y^- and Y^+ are endpoints of the temporal interval T_2.;

Table 1. Set *M* of basic endpoints' relations for two temporal intervals

M		
Group 1: {1,2,3}		
M_1	M_2	M_3
$X^- < Y^-$	$X^- > Y^-$	$X^- = Y^-$
Group 2: {4,5,6}		
M_4	M_5	M_6
$X^- < Y^+$	$X^- > Y^+$	$X^- = Y^+$
Group 3: {7,8,9}		
M_7	M_8	M_9
$X^+ < Y^-$	$X^+ > Y^-$	$X^+ = Y^-$
Group 4: {10,11,12}		
M_{10}	M_{11}	M_{12}
$X^+ < Y^+$	$X^+ > Y^+$	$X^+ = Y^+$

R - the set of *r* basic relations for temporal intervals. We define this set according to Allen [1,2]. The set of 13 Allen's interval relations is shown in Table 2;

Table 2. The set R of Allen's basic temporal relations

	T_1 Before T_2	R_1
	T_1 After T_2	R_2
	T_1 Meets T_2	R_3
	T_1 Met-by T_2	R_4
	T_1 During T_2	R_5
	T_1 Includes T_2	R_6
	T_1 Overlaps T_2	R_7
	T_1 Overlapped by T_2	R_8
	T_1 Starts T_2	R_9
	T_1 Started-by T_2	R_{10}
	T_1 Finishes T_2	R_{11}
	T_1 Finished by T_2	R_{12}
	T_1 Equals T_2	R_{13}

T - the set of *t* temporal intervals which correspond to the domain events;

P - the semantic predicate which defines piece of knowledge about temporal relationships in the basic domain by the following relation between the sets *T, R* and *S:*

$$P(T_a, R_k, T_b, S_i) = \begin{cases} 1, & \textit{if the knowledge source } S_i \textit{ uses } R_k \\ & \textit{to describe relation between } T_a \textit{ and } T_b; \\ 0, & \textit{otherwise.} \end{cases}$$

3. Deriving Most Supported Expert Opinion

To derive most supported opinion among all the experts about temporal relation we first construct the *RM* matrix $r \times m$ which defines relationship between the relations' sets *R* and *M* as it is shown in Table 3 by the following way:

$$\forall R_k \in R, \forall M_q \in M((R_k \Rightarrow M_q) \Rightarrow RM_{k,q});$$

Table 3. The *RM*-matrix

Relationships between Allen's basic temporal intervals' relations and endpoints relations												
RM	M_1	M_2	M_3	M_4	M_5	M_6	M_7	M_8	M_9	M_{10}	M_{11}	M_{12}
R_1	1	0	0	1	0	0	1	0	0	1	0	0
R_2	0	1	0	0	1	0	0	1	0	0	1	0
R_3	1	0	0	1	0	0	0	0	1	1	0	0
R_4	0	1	0	0	0	1	0	1	0	0	1	0
R_5	0	1	0	1	0	0	0	1	0	1	0	0
R_6	1	0	0	1	0	0	0	1	0	0	1	0
R_7	1	0	0	1	0	0	0	1	0	1	0	0
R_8	0	1	0	1	0	0	0	1	0	0	1	0
R_9	0	0	1	1	0	0	0	1	0	1	0	0
R_{10}	0	0	1	1	0	0	0	1	0	0	1	0
R_{11}	0	1	0	1	0	0	0	1	0	0	0	1
R_{12}	1	0	0	1	0	0	0	1	0	0	0	1
R_{13}	0	0	1	1	0	0	0	1	0	0	0	1

The technique of deriving the most supported opinion concerning certain pair T_a and T_b of events is the following. The experts give their votes concerning use of each temporal relation from the set R with this pair of events. After that we make the $SM^{a,b}$ matrix $n \times m$ which defines relationship between the set of knowledge sources S and set of basic relations M for each two fixed temporal intervals T_a and T_b by the following way:

$$\forall T_a, T_b \in T, \forall S_i \in S, \forall M_q \in M, \exists R_k \in$$

$$\in R((P(T_a, R_k, T_b, S_i) \& (R_k \Rightarrow M_q)) \Rightarrow SM_{i,q}^{a,b}).$$

The technique takes into account the rank of each expert which defines the weight of this expert vote among all other votes. Let r^v_i will be the rank of i-th expert before v-th voting ($0 < r_i^v < n$). The technique supposes that each expert rank is initially assigned to one:

$$r_i^1 = 1, \forall i (i = 1, \dots, n).$$

We construct the vector $VOTE^{a,b}$ which contains results of the current experts' voting concerning relation between intervals T_a and T_b derived from the matrix $SM^{a,b}$ as follows:

$$VOTE_q^{a,b} = abs(\varphi_q^{a,b} - \psi_q^{a,b}), \forall a,b \in \overline{1,t}, \forall q \in \overline{1,m},$$

where $\varphi_q^{a,b} = \sum_{\substack{i, \\ \forall i (SM_{i,q}^{a,b} = 1)}}^{n} r_i^v$, $\psi_q^{a,b} = \sum_{\substack{i, \\ \forall i (SM_{i,q}^{a,b} = 0)}}^{n} r_i^v$.

After that we derive $MSUP^{a,b}$ as the vector which contains most supported opinion concerning relation between intervals T_a and T_b derived as follows:

$$(\varphi_q^{a,b} - \psi_q^{a,b} > 0) \Rightarrow MSUP_q^{a,b}, \forall a,b \in \overline{1,t}, \forall q \in \overline{1,m}.$$

The number of conflicts con^v_i between opinion of i-th expert and the most supported opinion is calculated through all set M during the v-th voting:

$$con_i^v = \sum_{q}^{m} (SM_{i,q}^{a,b} \neq MSUP_q^{a,b}),$$

$$\forall a,b \in \overline{1,t}, \forall i \in \overline{1,n}, \forall v \in \overline{1,\infty}$$

This number is used to refine the rank of each expert after certain vote taking into account how close are the opinion of this expert and the most supported opinion.

The voting type technique supposes that the quality of the resulting opinion is better when the number of votes that are equal to the most supported opinion is large. We make the most supported opinion *quality Q* evaluation by the following way:

$$Q = \frac{\text{Votes accepted as most supported opinion}}{\text{All votes}};$$

$$Q_v^{a,b} = \frac{\sum_q^m VOTE_q^{a,b}}{m \cdot \sum_i^n r_i^v}.$$

4. Correction rules for the most supported opinion refinement

Not every most supported opinion can be accepted as the result because some parts of it may include conflicts. Thus we need certain syntactical analysis to handle conflicts using correction rules.

We use the following correction rules to check and refine the most supported opinion:

1. *If* <all the components from the same group of the most supported opinion are equal to zero>, *then* <that one which has the least vote should be changed to one>.

$$\forall a,b \in \overline{1,t}, \forall h, h \in \overline{1,4}((\neg MSUP_q^{a,b}, \forall q \in Group_h)\&$$
$$\&(\exists s \in Group_h (VOTE_s^{a,b} =$$
$$= \min(VOTE_{Group_h}^{a,b})))) \Rightarrow MSUP_s^{a,b}.$$

2. *If* <all the components from the same group of the most supported opinion are equal to zero and more then one of them has minimal vote in the group>, *then* <that one which corresponds to the relation of equivalence between temporal points should be changed to one>.

$$\forall a,b \in \overline{1,t}, \forall h, h \in \overline{1,4}((Group_h = \{q_1, q_2, q_3\})\&$$
$$\&(\neg MSUP_q^{a,b}, \forall q \in Group_h)\&(((VOTE_{q_1}^{a,b} =$$
$$= VOTE_{q_3}^{a,b}) \geq VOTE_{q_2}^{a,b}) OR((VOTE_{q_2}^{a,b} =$$
$$= VOTE_{q_3}^{a,b}) \geq VOTE_{q_1}^{a,b}))) \Rightarrow MSUP_{q_3}^{a,b}.$$

3. *If* <there are more than one components from the same group of the most supported opinion which are equal to one>, *then* <that one which has the least vote should be changed to zero>.

$$\forall a,b \in \overline{1,t}, \forall h, h \in \overline{1,4}((MSUP_s^{a,b} \& MSUP_q^{a,b}, \forall q,s \in$$
$$\in Group_h)\&(VOTE_s^{a,b} < VOTE_q^{a,b})) \Rightarrow \neg MSUP_s^{a,b}.$$

4. *If* <there are more than one equal to one components from the same group of the most supported opinion including the last one and they have the same vote>, *then* <those ones which are not correspond to the relation of equivalence between temporal points should be changed to zero>.

$$\forall a,b \in \overline{1,t}, \forall h, h \in \overline{1,4}((Group_h = \{q_1, q_2, q_3\})\&(\exists s \in$$
$$\in Group_h \neq q_3)\&(MSUP_{q_3}^{a,b} \& MSUP_s^{a,b} \&$$
$$\&(VOTE_{q_3}^{a,b} = VOTE_s^{a,b}))) \Rightarrow \neg MSUP_s^{a,b}.$$

5. Requirements to the expert's ranking (refinement strategy)

Mechanism of expert ranking is used to improve results of voting type processing of the multiple experts knowledge. The main formula used to refine ranks is the following:

$$r_i^{v+1} = r_i^v + \Delta r_i^v, \text{ where } \Delta r_i^v = \delta_i^v \cdot \frac{\mu^v \cdot (\mu^v - con_i^v)}{m},$$

$$\delta_i^v = \frac{r_i^v \cdot (n - r_i^v)}{n-1}, \ \mu^v = \frac{1}{n} \cdot \sum_j^n con_j^v.$$

This formula is based on the following strategy of refinement ranks:

- All the experts have the same initial rank, equal to 1.
- After each vote the rank of each expert should be recalculated.
- An expert improves his rank after some vote if his opinion has less conflicts with the most supported one than the average number of conflicts among all the experts. Otherwise he loses some part of his rank.
- An expert's rank should not be changed after some vote if expert does not participate it or his opinion has as many conflicts with the most supported one as the average number of conflicts among all the experts.
- An expert's rank should always be more than zero and less than number of experts.
- The value of punishment (prize) for presence (absence) of each conflict should be maximal for expert with rank equal to *n/2* (*n* - number of experts).
- The value of punishment (or prize) for presence (or absence) of each conflict should be aspire to zero for expert whose rank is close to zero or to *n*.

6. Example of deriving the most supported expert opinion

In this chapter we will consider the example of deriving the most supported opinion of four experts concerning a temporal relation. Let the four experts are asked to express their opinion about temporal relation between two abstract temporal intervals: first vote - between intervals

T_1 and T_2; second vote - between intervals T_3 and T_4; third vote - between intervals T_5 and T_6.

We supposed that ranks of all experts at the very beginning (before the first vote) is equal to one. Let the experts express their opinions during the *first vote* by the following way:

Expert 1: "T_1 during T_2 ". *Expert 2:* "T_1 overlaps T_2 ".

Expert 3: "T_1 starts T_2 ". *Expert 4:* "T_1 finished by T_2 ".

The results of deriving the most supported opinion for the first vote are presented in Table 4.

Table 4. The example (first vote)

$SM^{1,2}$	M_1	M_2	M_3	M_4	M_5	M_6	M_7	M_8	M_9	M_{10}	M_{11}	M_{12}
S_1 (R_5)	0	1	0	1	0	0	0	1	0	1	0	0
S_2 (R_7)	1	0	0	1	0	0	0	1	0	1	0	0
S_3 (R_9)	0	0	1	1	0	0	0	1	0	1	0	0
S_4 (R_{12})	1	0	0	1	0	0	0	1	0	0	0	1
VOTE	0	+2	+2	+4	+4	+4	+4	+4	+4	+2	+4	+2
MSUP	0	0	0	1	0	0	0	1	0	1	0	0
Correction	1	0	0	1	0	0	0	1	0	1	0	0
Results:												
Most supported opinion: "T_1 overlaps T_2 ".												
Total votes: 48								Positive votes: 36				
Quality: 0.75												

Expert ranking in the example will changed after the first vote as it is shown in Table 5.

Table 5. Ranks refinement in the example (after first vote)

Opinions	M_1	M_2	M_3	M_4	M_5	M_6	M_7	M_8	M_9	M_{10}	M_{11}	M_{12}
Expert 1	0	1	0	1	0	0	0	1	0	1	0	0
Expert 2	1	0	0	1	0	0	0	1	0	1	0	0
Expert 3	0	0	1	1	0	0	0	1	0	1	0	0
Expert 4	1	0	0	1	0	0	0	1	0	0	0	1
Most supported	1	0	0	1	0	0	0	1	0	1	0	0

Ranks' refinement				
Expert	Number of conflicts con^1_i	Rank before voting r^1_i	Rank add (lost) Δr^1_i	Rank after voting r^2_i
Expert 1	2	1	- 0.0625	0.9375
Expert 2	0	1	+ 0.1875	1.1875
Expert 3	2	1	- 0.0625	0.9375
Expert 4	2	1	- 0.0625	0.9375
Average	1.5	1	0	1

Let the experts express their opinions during the *second vote* by the following way:
Expert 1: "T_3 after T_4 " ($r^2_1 =$ 0.9375).
Expert 2: "T_3 meets T_4 " ($r^2_2 =$ 1.1875).
Expert 3: "T_3 overlapped by T_4 " ($r^2_3 =$ 0.9375).
Expert 4: "T_3 before T_4 " ($r^2_4 =$ 0.9375).

The results of deriving the most supported opinion for the second vote are presented in Table 6.

Table 6. The example (second vote)

$SM^{3,4}$	M_1	M_2	M_3	M_4	M_5	M_6	M_7	M_8	M_9	M_{10}	M_{11}	M_{12}
S_1 (R_2)	0	1	0	0	1	0	0	1	0	0	1	0
S_2 (R_3)	1	0	0	1	0	0	0	0	1	1	0	0
S_3 (R_8)	0	1	0	1	0	0	0	1	0	0	1	0
S_4 (R_1)	1	0	0	1	0	0	1	0	0	1	0	0
VOTE	+0.25	+0.25	+4	+2	+2	+4	+2	+0.25	+1.625	+0.25	+0.25	+4
MSUP	1	0	0	1	0	0	0	0	0	1	0	0
Correction	1	0	0	1	0	0	0	1	0	1	0	0

Results:

Most supported opinion: "T_3 overlaps T_4 ".

Total votes: 48 Positive votes: 20.875
Quality: 0.435

Expert ranking in the example will changed after the second vote as it is shown in Table 7.

Table 7. Ranks refinement in the example (after second vote)

Opinions	M_1	M_2	M_3	M_4	M_5	M_6	M_7	M_8	M_9	M_{10}	M_{11}	M_{12}
Expert 1	0	1	0	0	1	0	0	1	0	0	1	0
Expert 2	1	0	0	1	0	0	0	0	1	1	0	0
Expert 3	0	1	0	1	0	0	0	1	0	0	1	0
Expert 4	1	0	0	1	0	0	1	0	0	1	0	0
Most supported	1	0	0	1	0	0	0	1	0	1	0	0

Ranks' refinement

Expert	con^2_i	δ^2_i	r^2_i	$\Delta\, r^2_i$	r^3_i
Expert 1	6	0.957	0.9375	- 0.6978	0.2397
Expert 2	2	1.1133	1.1875	+ 0.487	1.6745
Expert 3	4	0.957	0.9375	- 0.1396	0.7979
Expert 4	2	0.957	0.9375	+ 0.4187	1.3562
Average	3.5	0.996	1	+ 0.017	1.017

Let the experts express their opinions during the *third vote* by the following way:

Expert 1: "T_5 includes T_6 " (r^3_1 = 0.2397).

Expert 2: "T_5 finished by T_6 " (r^3_2 = 1.6745).

Expert 3: "T_5 after T_6 " (r^3_3 = 0.7979).

Expert 4: "T_5 overlapped by T_6 " (r^3_4 = 1.3562).

The results of deriving the most supported opinion for the third vote are presented in Table 8.

Table 8. The example (third vote)

$SM^{5,6}$	M_1	M_2	M_3	M_4	M_5	M_6	M_7	M_8	M_9	M_{10}	M_{11}	M_{12}
S_1 (R_6)	1	0	0	1	0	0	0	1	0	0	1	0
S_2 (R_{12})	1	0	0	1	0	0	0	1	0	0	0	1
S_3 (R_2)	0	1	0	0	1	0	0	1	0	0	1	0
S_4 (R_8)	0	1	0	1	0	0	0	1	0	0	1	0
VOTE	+0.24	+0.24	+4.068	+3.27	+3.27	+4.068	+4.068	+4.068	+4.068	+4.068	+0.719	+0.719
MSUP	0	1	0	1	0	0	0	1	0	0	1	0
Correction	0	1	0	1	0	0	0	1	0	0	1	0

Results:

Most supported opinion: "T_5 overlapped by T_6 ".

Total votes: 48.816 Positive votes: 32.866

Quality: 0.673

Expert ranking in the example will changed after the third vote as it is shown in Table 9.

Table 9. Ranks refinement in the example (after third vote)

Opinions	M_1	M_2	M_3	M_4	M_5	M_6	M_7	M_8	M_9	M_{10}	M_{11}	M_{12}
Expert 1	1	0	0	1	0	0	0	1	0	0	1	0
Expert 2	1	0	0	1	0	0	0	1	0	0	0	1
Expert 3	0	1	0	0	1	0	0	1	0	0	1	0
Expert 4	0	1	0	1	0	0	0	1	0	0	1	0
Most supported	0	1	0	1	0	0	0	1	0	0	1	0

Ranks' refinement

Expert	con^3_i	δ^3_i	r^3_i	Δr^3_i	r^4_i
Expert 1	2	0.3	0.2397	0	0.2397
Expert 2	4	1.298	1.6745	- 0.4327	1.2418
Expert 3	2	0.852	0.7979	0	0.7979
Expert 4	0	1.195	1.3562	+ 0.3983	1.7545
Average	2	0.911	1.017	- 0.0085	1.0085

One can see that after third vote the rank of first expert is such that he cannot essentially effect the most supported opinion. The rank of the fourth expert makes his opinion the most weighty among all the experts.

However it also obvious that he can lose his rank in future if all other experts will vote similarly against his opinion.

7. Example of changing the order of the domain description

In this chapter we will consider the same example with same temporal intervals T_1 - T_6 . We will change only the order of the domain description using the same opinions of the same experts.

We first consider the case of description of the temporal relation between intervals T_5 and T_6, then between intervals T_3 and T_4, and then between intervals T_1 and T_2.

The goal of such attempt is to analyse the differences in the resulting experts ranks in both examples.

The results of deriving the most supported opinion and results of the experts ranks refinement for the first-third vote in the "reverse-order" example are presented in Tables 10-15.

Table 10. The reverse example (first vote)

$SM^{5,6}$	M_1	M_2	M_3	M_4	M_5	M_6	M_7	M_8	M_9	M_{10}	M_{11}	M_{12}
S_1 (R_6)	1	0	0	1	0	0	0	1	0	0	1	0
S_2 (R_{12})	1	0	0	1	0	0	0	1	0	0	0	1
S_3 (R_2)	0	1	0	0	1	0	0	1	0	0	1	0
S_4 (R_8)	0	1	0	1	0	0	0	1	0	0	1	0
VOTE	0	0	+4	+2	+2	+4	+4	+4	+4	+4	+2	+2
MSUP	0	0	0	1	0	0	0	1	0	0	1	0
Correction	1*	1*	0	1	0	0	0	1	0	0	1	0

Results:

Most supported opinion: "T_5 includes T_6 or T_5 overlapped by T_6".

Total votes: 48 Positive votes: 32

Quality: 0.67

Table 11. Ranks refinement in the reverse example (after first vote)

Opinions	M_1	M_2	M_3	M_4	M_5	M_6	M_7	M_8	M_9	M_{10}	M_{11}	M_{12}
Expert 1	1	0	0	1	0	0	0	1	0	0	1	0
Expert 2	1	0	0	1	0	0	0	1	0	0	0	1
Expert 3	0	1	0	0	1	0	0	1	0	0	1	0
Expert 4	0	1	0	1	0	0	0	1	0	0	1	0
Most supported	1*	1*	0	1	0	0	0	1	0	0	1	0

Ranks' refinement

Expert	Number of conflicts con^1_i	Rank before voting r^1_i	Rank add (lost) Δr^1_i	Rank after voting r^2_i
Expert 1	1	1	+ 0.17	1.17
Expert 2	3	1	- 0.17	0.83
Expert 3	3	1	+ 0.17	0.83
Expert 4	1	1	- 0.17	1.17
Average	2	1	0	1

Table 12. The reverse example (second vote)

$SM^{3,4}$	M_1	M_2	M_3	M_4	M_5	M_6	M_7	M_8	M_9	M_{10}	M_{11}	M_{12}
S_1 (R_2)	0	1	0	0	1	0	0	1	0	0	1	0
S_2 (R_3)	1	0	0	1	0	0	0	0	1	1	0	0
S_3 (R_8)	0	1	0	1	0	0	0	1	0	0	1	0
S_4 (R_1)	1	0	0	1	0	0	1	0	0	1	0	0
VOTE	0	0	+4	+1.83	+1.83	+4	+1.83	0	+2.17	0	0	+4
MSUP	0	0	0	1	0	0	0	0	0	0	0	0
Correction	1*	1*	0	1	0	0	0	1	0	1*	1*	0

Results:

Most supported opinion: "T_3 during T_4 or T_3 includes T_4 or T_3 overlaps T_4 or T_3 overlapped by T_4".

Total votes: 48 Positive votes: 19.66

Quality: 0.41

Table 13. Ranks refinement in the reverse example (after second vote)

Opinions	M_1	M_2	M_3	M_4	M_5	M_6	M_7	M_8	M_9	M_{10}	M_{11}	M_{12}
Expert 1	0	1	0	0	1	0	0	1	0	0	1	0
Expert 2	1	0	0	1	0	0	0	0	1	1	0	0
Expert 3	0	1	0	1	0	0	0	1	0	0	1	0
Expert 4	1	0	0	1	0	0	1	0	0	1	0	0
Most supported	1*	1*	0	1	0	0	0	1	0	1*	1*	0

Ranks' refinement

Expert	con^2_i	δ^2_i	r^2_i	Δr^2_i	r^3_i
Expert 1	6	1.1037	1.17	- 0.161	1.009
Expert 2	4	0.877	0.83	- 0.121	0.709
Expert 3	2	0.877	0.83	+ 0.3631	1.1931
Expert 4	4	1.1037	1.17	- 0.161	1.009
Average	3.5	0.9904	1	- 0. 08	0.98

Table 14. The reverse example (third vote)

$SM^{1,2}$	M_1	M_2	M_3	M_4	M_5	M_6	M_7	M_8	M_9	M_{10}	M_{11}	M_{12}
S_1 (R_5)	0	1	0	1	0	0	0	1	0	1	0	0
S_2 (R_7)	1	0	0	1	0	0	0	1	0	1	0	0
S_3 (R_9)	0	0	1	1	0	0	0	1	0	1	0	0
S_4 (R_{12})	1	0	0	1	0	0	0	1	0	0	0	1
VOTE	+0.484	+1.902	+1.534	+3.92	+3.92	+3.92	+3.92	+3.92	+3.92	+1.902	+3.92	+1.902
MSUP	0	0	0	1	0	0	0	1	0	1	0	0
Correction	1	0	0	1	0	0	0	1	0	1	0	0

Results:

Most supported opinion: "T_1 overlaps T_2 ".

Total votes: 47.0412 Positive votes: 35.165
Quality: 0.7475

Table 15. Ranks refinement in the reverse example (after third vote)

Opinions	M_1	M_2	M_3	M_4	M_5	M_6	M_7	M_8	M_9	M_{10}	M_{11}	M_{12}
Expert 1	0	1	0	1	0	0	0	1	0	1	0	0
Expert 2	1	0	0	1	0	0	0	1	0	1	0	0
Expert 3	0	0	1	1	0	0	0	1	0	1	0	0
Expert 4	1	0	0	1	0	0	0	1	0	0	0	1
Most supported	1	0	0	1	0	0	0	1	0	1	0	0

Ranks' refinement

Expert	con^3_i	δ_i^3	r^3_i	Δr^3_i	r^4_i
Expert 1	2	1.006	1.009	-0.0629	0.9431
Expert 2	0	0.778	0.709	+ 0.1459	0.8549
Expert 3	2	1.116	1.1931	-0.07	1.1231
Expert 4	2	1.006	1.009	-0.0629	0.9431
Average	1.5	0.977	0.98	- 0.0124	0.967

One can see that the situation is changed almost totally. The first and the second votes in the reverse example have ambiguity in the selection of the most supported opinion. This happened because no one of the correction rules can be applied. One interesting fact that the second vote gave four alternatives and three of them are different from the initial opinions of experts. The resulting rank of each expert is also depends on the order of the domain description. The continuation of the experiment with the computer has been made so that new experts ranks obtained after three votes were applied with the same domain and the same order. Such iterative process of the same domain description leads after several steps to an unique relation for each domain pair.

8. Conclusion

The method can also be used to *derive the most supported knowledge* in domains that have a well-defined set of basic relations (such as the set *M*) and a set of compound relations (such as the set *R*). In those cases, experts are allowed to give incomplete or incorrect knowledge about a relation from the set *R* because it can be handled by deriving the most supported opinion of multiple experts through the set *M*.

Ranking technique in this research supports experts whose opinion is close to the most supported one. It even may happen that only one expert remains after several votes whose rank becomes more than all other ranks together. In many applications, the most supported knowledge is not the best one. Moreover the talent individuals can easily lose their rank if they are thinking not like others. That is why method should be developed to pick up and classify experts whose opinions are the most different from the most supported opinion, and then try to take them into account.

The question is also open is it good or not that the order of describing domain events effects the result of expert ranking. If one will continue the example further then he can see, that if the order of voting will changed again then ranks of experts after every three votes will be different.

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