Computing Trust Resultant using Intervals

Hassan Shakeri
Abbas Ghaemi Bafghi
Hadi Sadoghi Yazdi

ISCISC'11
September 14-15 2011
Ferdowsi University of Mashhad

Outline

- Introduction
- Role of Confidence in trust management
- Representation of trust and confidence using interval notation
- Trust interval summation
- Trust inference algorithm
- Experiments and results
- Conclusion and future works

Introduction

- Recently the concept of trust has obtained an increasingly important role in various fields of computing science.
- Trust is a subjective expectation an agent has about another's future behavior based on the history of their encounters.

3

Introduction

- Trust has the transitivity property:
  - If A trust B and B trust C, then A may trust C.
  - Used in trust propagation, especially when there is no link between a pair of entities in the web of trust.
  - However there is discussion on how much transitivity is valid and which formula or algorithm should be used for calculating the propagated trust value in each field.

4

Role of Confidence in Trust Management

- Role of Confidence in Trust Propagation:
  - When an intermediate node reports the value of trust to the target node, how confident this recommendation is and how the level of confidence should be applied in final trust estimation?
  - When two or more intermediate nodes with known confidence levels report the value of trust for the target, how the resultant of these opinions should be computed and what is the confidence in this resultant?

5

Role of Confidence in Trust Management

Example:

- S receives two values 0.7 and 0.4 on the trustworthiness of D form A and B respectively.
- Values of S's confidence in A's and B's reports are 0.3 and 0.8, respectively.
- What is the resultant of these two different reports?
- How confident this final S's judgment is?

6

Role of Confidence in Trust Management

- Many of research works have not taken into account the role of confidence in trust management.
- Some have used the weighted-averaging method to consider the effect of the confidence in computing trust resultant.
- We introduce a novel idea to use the concept of intervals for representation of trust and confidence both together.
- We then propose a method for evaluating the resultant of two or more trust opinions.
- We call this method summation of trust intervals.

7

Role of Confidence in Trust Management

- One of the key works in this area is Josang's one.
- Josang represents an opinion on trust as a triple
  {b, d, u}
- b = belief, d = disbelief u = uncertainty
- Josang's formula for calculating the resultant of two opinions:

8

Role of Confidence in Trust Management

$$w_p^{A,B} = w_p^A \oplus w_p^B = \{b_p^{A,B}, d_p^{A,B}, u_p^{A,B}\}$$

$$b_p^{A,B} = \frac{b_p^A u_p^B + b_p^B u_p^A}{u_p^A + u_p^B - u_p^A u_p^B}$$

$$d_p^{A,B} = \frac{d_p^A u_p^B + d_p^B u_p^A}{u_p^A + u_p^B - u_p^A u_p^B}$$

$$u_p^{A,B} = \frac{u_p^A u_p^B}{u_p^A + u_p^B - u_p^A u_p^B}$$

9

Representation of trust and confidence using interval notation

- Confidence: the capacity in which an entity is assured about its own or another entity's assessment on a target entity's trustworthiness level.
- Example:

  S asks entity A about D's trustworthiness and A replies as 0.7. However S's (or A's itself) confidence in this opinion may be 0.8.
- We propose integrating these two values in a new representation using intervals:

  TI = [C*T, C*T+1−C] (1)

10

Representation of trust and confidence using interval notation

$$L = C*T + (1-C)*0 = C*T \qquad (2)$$

$$U = C*T + (1-C)*1 = C*T+1-C \qquad (3)$$

11

Representation of trust and confidence using interval notation

Example:

Suppose T=0.7. Then

C = 0 ➔ TI = [0, 1]
C = 0.5 ➔ TI = [0.35, 0.85]
C = 0.8 ➔ TI = [0.56, 0.76]
C = 1 ➔ TI = [0.7, 0.7]

12

Representation of trust and confidence using interval notation

- Using an integrated interval for representing both trust and confidence is clearer and more intuitive than using two distinct variables. However we can again extract the values of trust and confidence from the trust interval anytime needed:

$$T = \frac{L}{1 + L - U} \qquad C = \frac{L}{T}$$

13

Representation of trust and confidence using interval notation

- Our proposed idea of interval trust is similar to the Josang's notation
- However we believe that our notation is more intuitive.
- These two notations are convertible to each other. For example:

$L = b$ (6)

$U = 1 - d$ (7)

14

Trust interval summation

- Suppose that S asks A and B to report their opinions about D.
- A and B send their replies in the form of trust interval, $[L_A, U_A]$ and $[L_B, U_B]$
- To determine what is the final assessment of S on D's trustworthiness, and in what capacity this estimation is confident, we define a special kind of **summation operator for trust intervals**.

Trust interval summation

Trust Interval Summation:

$$L_C = \frac{L_A U_B + L_B U_A - 2L_A L_B}{W_A + W_B - W_A W_B}$$

$$U_C = \frac{U_A U_B - L_A L_B}{W_A + W_B - W_A W_B}$$

$W_A = U_A - L_A$
$W_B = U_B - L_B$

Trust interval summation

TABLE I SUM (RESULTANT) OF SOME TRUST INTERVAL PAIRS

Intervals	[0, 0.25]	[0, 0.5]	[0, 0.75]	[0,1]	[0.25, 0.5]	[0.25, 0.75]	[0.25, 1]	[0.5, 0.75]	[0.5, 1]	[0.75, 1]
[0, 0.25]	[0, 0.14]	[0, 0.2]	[0, 0.23]	[0, 0.25]	[0.14, 0.29]	[0.1, 0.3]	[0.08, 0.31]	[0.29, 0.43]	[0.2, 0.4]	[0.43, 0.57]
[0, 0.5]		[0, 0.33]	[0, 0.43]	[0, 0.5]	[0.2, 0.4]	[0.17, 0.5]	[0.14, 0.57]	[0.4, 0.6]	[0.33, 0.67]	[0.6, 0.8]
[0, 0.75]			[0, 0.6]	[0, 0.75]	[0.23, 0.46]	[0.21, 0.64]	[0.2, 0.8]	[0.46, 0.69]	[0.43, 0.86]	[0.69, 0.92]
[0, 1]				[0,1]	[0.25, 0.0.5]	[0.25, 0.75]	[0.25, 1]	[0.5, 0.75]	[0.5, 1]	[0.75, 1]
[0.25, 0.5]					[0.29, 0.43]	[0.3, 0.5]	[0.31, 0.54]	[0.43, 0.57]	[0.4, 0.6]	[0.57, 0.71]
[0.25, 0.75]						[0.33, 0.67]	[0.36, 0.79]	[0.5, 0.7]	[0.5, 0.83]	[0.7, 0.9]
[0.25, 1]							[0.4, 1]	[0.54, 0.77]	[0.57, 1]	[0.77, 1]
[0.5, 0.75]								[0.57, 0.71]	[0.6, 0.8]	[0.71, 0.86]
[0.5, 1]									[0.67, 1]	[0.8, 1]
[0.75, 1]										[0.86, 1]

Trust interval summation – Properties

Properties of Interval Trust Summation:

1) Sum of two similar or equal trust intervals reflects the confidence increment as the opinions confirm each other.

- Example:
  [0.25, 0.5] + [0.25, 0.5] = [0.29, 0.43]

Trust interval summation – Properties

2) If we add more than two similar or equal opinions, the width of the result interval becomes even narrower.

We may consider the sum of multiple equal opinions as a kind of scalar by interval multiplication.

19

Trust interval summation – Properties

TABLE II. MULTIPLICATION OF SOME EQUAL OPINIONS (MULTIPLES OF [0.25, 0.5])

1*[0.25, 0.5]	2*[0.25, 0.5]	3*[0.25, 0.5]	4*[0.25, 0.5]	5*[0.25, 0.5]
[0.25, 0.5]	[0.29, 0.43]	[0.3, 0.4]	[0.31, 0.38]	[0.31, 0.37]

20

Trust interval summation – Properties

3) If we add some different opinions, the sum reflects a reasonable resultant.

Example 1:

[0, 0.5] + [0.75, 1] = [0.6, 0.8]

Example 2:

P1 = [0.6, 0.8], P2 = [0.6, 0.8], P3 = [0.5, 0.75], P4 = [0.1, 0.3]

P1 + P2 = [0.67, 0.78]

(P1 + P2) + P3 = [0.67, 0.75]

((P1 + P2) + P3) + P4 = [0.53, 59]

Trust inference algorithm

Function InferTrust
Inputs:
  Trust Network (TN),
  source node (n_0),
  sink node (n_∞)
Output:
  Inferred trust which describes the amount of trust that the source has for the sink (TI_{sum})
Begin
  TI_{sum} = [0, 1]
  For all nodes n_k where there is an arc from n_k to n_∞ do
  Begin
    C = n_0's confidence in n_k's opinions
    T = n_k's Trust for n_∞
    TI_k = trust interval computed using Equation (1)
    TI_{sum} = TI_{sum} + TI_k (Using Equations (8) and (9))
  End
  Return TI_{sum}
End

Trust inference algorithm – Confidence Estimation Subalgorithm

Function EstimateConfidence
Inputs:
    Trust Network (TN),
    source node (n_0),
    appraiser node (n_k)
Output:
     The confidence n_0 has in n_k's opinions
Begin
    sum = 0
    counter = 0
    For all nodes n_i in TN
    If $T[n_0, n_i] \neq 0$ and $T[n_k, n_i] \neq 0$
    Begin
            sum = sum + $|T[n_0, n_i] - T[n_k, n_i]|$
            counter = counter + 1
    End
    MeanDiff = sum / counter
    C = 1 – MeanDiff
    Return C
End

23

Experiments and Results

- To Compare the accuracy of the resultant calculated using our method and the weighted-averaging method, we applied both methods to the dataset of Advogato.
- This dataset contains information of trust among the members of an internet community of programmers.

24

Experiments and Results

- Evaluation technique: leave-one-out
  For any pairs of nodes v_i and v_j which direct trust of v_i for v_j is available, we also calculate the indirect value of trust from v_i to v_j using the algorithm.
- Evaluation Measures:
  - Correlation between direct and indirect trust
  - Mean of absolute error between direct and indirect trust

25

Experiments and Results

TABLE II. MULTIPLICATION OF SOME EQUAL OPINIONS (MULTIPLES OF [0.25, 0.5])

1*[0.25, 0.5]	2*[0.25, 0.5]	3*[0.25, 0.5]	4*[0.25, 0.5]	5*[0.25, 0.5]
[0.25, 0.5]	[0.29, 0.43]	[0.3, 0.4]	[0.31, 0.38]	[0.31, 0.37]

26

Conclusion and Future Works

- We introduced a novel method for representing trust and confidence concepts using intervals.
- We then defined a special kind of summation on the trust intervals which may be used in calculating the resultant of opinions.
- Our method provides a good approach to combine opinions confirming or contradicting one another.

Conclusion and Future Works

- In future we intend to investigate the effect of measures other than similarity in confidence.
- We will also study the propagation of interval trust in a trust chain.
- We are going to study the applications of intervals in
  - analyzing the sources of uncertainty in trust management
  - eliminating subjectivity from trust assessment
  - clustering nodes of the web of trust.

Thanks

for your attention