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Multi-Dimensional E-commerce Trust Evaluation Method

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Abstract—In the last decade, e-commerce has been grown rapidly and become a familiar tool of shopping for many people. However, some people still have concerns while making online purchases due to its uncertain attributes. In fact, there are many online consumers have suffered from monetary loose problem due to some reasons which the lack of the trust in e-commerce is one of them. Therefore, there is a great demand for a mechanism that helps to evaluate the trust throughout the online transactions. One of them is the existing mechanism of the trust management which is used in some e-commerce websites (e.g. eBay)[1]. Such a mechanism evaluates the trust by computing a trust value of any seller only based on the previous rating of the past transactions. Therefore, the trust value is only able to show the general status of the trust without taking into the account the new transaction. Consequently, there is a great possibility for the frauds to be committed by some of the malicious people. For example, some of them can easily build a good reputation by making many transactions by selling cheap products with good qualities and start to commit frauds by selling more expensive products. This kind of frauds is named by [1] as the value imbalance problem. Therefore, there is a great demand for a trust evaluation mechanism which consider the new transaction as well as the past transactions. In this paper, we propose a new method which considers three dimensions that play important roles in any online transaction to help the buyers to detect the frauds. This method measures the similarity between the new transaction and the past transactions in the products types dimension, the number of the products sold dimension and the transactions amounts dimension.

Index Terms—transaction similarity; trust evaluation; ecommerce ; contextual trust

I. INTRODUCTION

Trust is essential at every step in our daily lives, which also makes it a crucial factor of society. It is difficult to explain what trust means to us in just a few words, but some options include honesty, confidence, faith, surety, belief, etc. According to [2] , [3] trustworthiness can be equated with a social context in some ways for example, by referring to the interaction history, social reputation, word of mouth from a reliable third party, or certification, etc., of a concept, person, product, or service. trust can be defined in different ways because of its nature: the context of trusts sensitivity indicates that its definition might change with environment and time [4]. The reputation mechanism, which is a concept related to trust, is used as one of the most common ways to measure the trustworthiness in certain environments.

Reputation has been defined as a form of belief by the Compact Oxford English dictionary, which states that reputation is the belief or opinions that are generally held about someone or something [5]. It is also worth mentioning that reputation is a concept related to trust but holds a slightly different meaning, so the two can be used without confusing them. In [6] has defined reputation as an expectation about an agents behaviour based on information about or observations of its past behaviour

Some e-services websites such as eBay use simple mechanism of trust management to give some information of trust to buyers before being in any transaction. The buyers can also rate the seller after any transaction by giving him/her (Negative, Neutral or Positive). These ratings are accumulated from the buyers and a single feedback is computed to show the trust status of the seller over the past transactions.

There are many models have proposed by researchers depending on only the past transactions to represent the reputation of a seller. However, most of these models show only the general status of trust while the buyer might have concerns about the new transactions. The buyers might not rely on this trust value, which only infer to the trust level of past transaction. As a result, the buyers might be vulnerable to be attacked by the malicious sellers. For example, a good reputation of a malicious seller can be simply built up by

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[1] http://https://www.ebay.co.uk/

selling cheap products or services and then starting cheating the buyers after obtaining a good reputation. This kind of attack has been mentioned and named by [1] as the value imbalance problem.

In this paper, the proposed method can be used to evaluate the contextual trust that can prevent the value imbalance problem by identifying the malicious transaction. This method is mainly based on three dimensions (the sold product type dimension, the number of product sold dimension and the transaction amount dimension) which play the main roles in term of explaining the contexts of transaction. It also can be used in term of measuring the similarity between the past transactions and the new transaction. Section II shows some models which take in the consideration the relationship between the similarity evaluation and the trust evaluation. Section III shows the methodology that is used in the proposed method and how this method works.

II. RELATED WORK

In the literature, there are some models of trust evaluation have been considered in some applications. In this section, we divided the trust evaluation models into two groups according to their relationships with the context information.

A. Trust Evaluation without Contextual Information

Most of the existing trust evaluation models are proposed in several applications for example in P2P networks. The general value of a peer is calculated by aggregating the binary trust ratings(0,1) [7]. These models [8] [9] [10] [11] do not consider the contextual information and only focus on a signal or final trust level to show the general trust status of a seller. As a result, the buyer might not be able to know how the seller has obtained this high value of trust, which makes it difficult to predict the success for completing the forthcoming transactions in trustworthy environment.

B. Trust Evaluation with contextual Information

On the other hand, there are some models taking into account the relationship between the evaluation of trust and context information.

- **Multi-Dimensional Trust Evaluation models :**
  In [12] proposes Multi-Dimensional Trust Model (MDT) which is based on Marsh's general trust model. However, MDT is a slightly different because the author takes into the accounts some attributes of the transaction such as time, quality and cost and a buyer can specify the weight of the attributes for trust computation. In this models, the buyers evaluate the sellers based on their own direct experiences. The author mentioned that MDT can be considered as a complementary to general trust as the buyers can get the trust value of a seller in a specific situation from different dimension for example, the trust value of a seller can be trustworthy in selling cars from different dimensions such as time to handle the transaction and the quality of cars but the buyer might not be sure about the trust of the seller if she/he sells

something else. Therefore, MDT is not able to prevent the value imbalance problem.

In [13] proposes REGRET system, which is used to enhance the calculation of trust and reputation values. This system uses a framework called SuppWorld in order to test the complicated models. REGRET system is similar to MDT, the trust and reputation values of sellers are evaluated from different dimensions and buyers can weight these dimensions by their own experiences and general reputation.

- **Contextual Inheritance Trust Evaluation Models (CI):** Strang et al. [14] mentioned that " ontologies are considered as a promising instrument to specify concepts and interrelations". Consequently, many researchers have used the ontology as a structure in order to analysis the awareness of context trust. Uschold et al. in [15] explained the related ontology conception. Generally, although, the ontology is a conceptual model, it also can explain the relationship between different concepts. These relationships could be either 'a kind of' referred to inheritance, 'a part of' referred to part and overall and 'an instance of'.

  Some studies deal with the issues of contextual evaluation by focusing on the main conception of the inherited trust. in [16] mentioned that context can be hierarchically structured. For instance, if I rust my brother to drive me to the airport, so I can give him my cars keys. Then 'giving him my cars keys' is considered as subset of the access rights of driving my car. In [17] proposes a hierarchical model of trust in contexts (HMTC) which can be used to discover the relations between contexts. The authors believes that in order to deduce the trust value from one context to another, there is a need to identify hierarchical structures between contexts. Thus their model differs from ours, because in contextual properties such as amount category, a hierarchy is a tree structure and we have considered the number of transactions that falls in a certain range as been discussed in the methodology section

- **Contextual Similarity Trust Evaluation Models**
  Mui in [18] summarised the description of context-based trust evaluation in the following example. A who has not been in an interaction with B. A asks other parties in the same context what they rate B (before being in any interaction with B). If the weighted sum of the rating from other parties is bigger than the certain threshold, the trust between A and B will be established. However, in order to evaluate the forthcoming transaction, the buyer depends on the others ratings (who have been in a transaction with the same seller before) and then compare context similarity between two buyers. [14] compared between different approaches to model context and based on their comparison, they believe that key value-based model is not effective to describe the complexity in the relationship within the context. For example, Digital projector and Inkjet network printer are not same products but they both

have similarity because both are types of computer output devices. For this reason, buyers may trust seller and buy the provided printer because they know this seller has a good reputation on selling a good quality digital projector. They also believe that ontology is a good instrument to identify concepts and interrelations [19] propose Context-Aware Trust model (CAT) which is used to compare the context similarity by using key values, which can describe a certain context to some extent for open and dynamic system. They introduce a parameter of context-similarity.

III. MULTI-DIMENSIONAL E-COMMERCE TRUST EVALUATION METHOD BASED ON CONTEXTS, INHERITANCE AND SIMILARITY

In this paper, a trust evaluation method is applied in e-services environment (e.g. e- commerce). It is generally based on the comparisons within three dimensions; a) the similarity between the products types, the similarity between the number of the item sold (T_{TN}) and the similarity of the transactions amounts (T_{AM}) which play the most important role in the explanation of the transaction contexts. The final trust value (T_{Final}) is identified as follows:

$$T_{Final} = \frac{T_{TN} + T_{AM}}{2} \tag{1}$$

There are some contextual properties of any online transaction such as products and services tree, the Number of products sold and transaction amount which are considered as one of the main properties. Therefore, they have major impacts on establishing the trust between the users in e-commerce websites. The products and services types trees in the e-commerce website can also assist the users to make the transactions in trustworthy environments. Additionally, the transaction amount dimension play an important role in the trust evaluation because the buyers might have concerns if the seller starts selling a new product which is already in the same tree that he/she used to sell but in a higher or a lower prices which can create a possibility to commit a fraud.

1) TRUST EVALUATION METHOD BASED ON PRODUCT TYPE SIMILARITY

This section shows the first factor in the proposed method (T_{tn}) that can be used to measure the similarity between the product types in addition to the number of the products sold within the proposed tree as shown in Fig. 1.

The Modified Products and Services Tree ($MTree_{ps}$)
There are some existing categorizations which are used to divide the products in the market into groups such as eCl@ss. eCl@ss is considered as a hierarchical classification which uses an ontology structure that includes a four-level hierarchy. Each level is represented by two character numerical value while the last level is enriched with a set of attributes. The used tree in this method is created based on eCl@ss. In the addition to the products
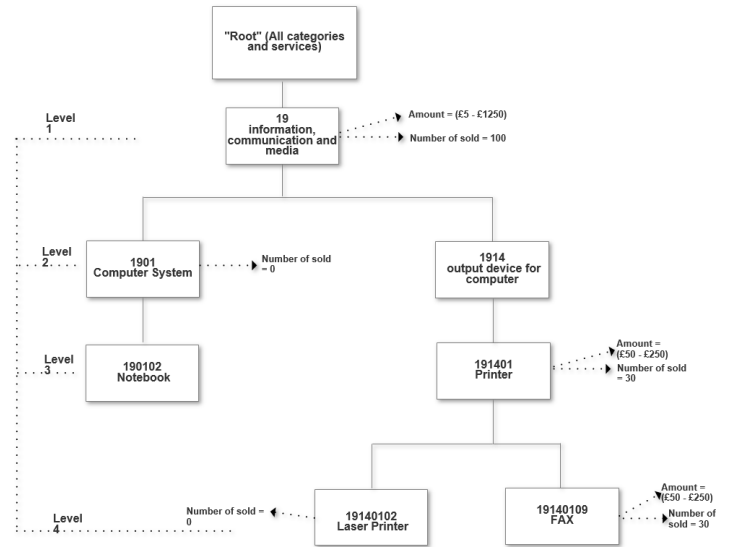

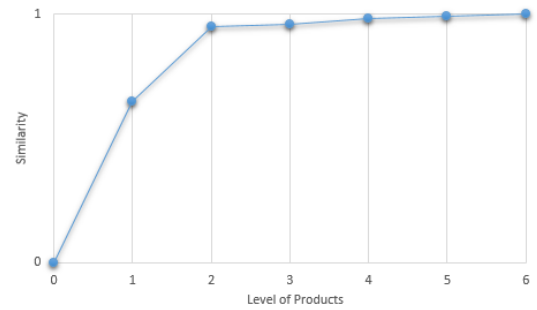Fig. 1. The Modified Products and Services Tree ($MTree_{ps}$)

Fig. 2. The relationship between the similarity value and the level of products

types, we added the number of item sold and the price of every sold item. The tree has number of levels and every level has a code which is taken from eCl@ss and the price range of selling every item as shown Fig.1.
The similarity between the products types (T_{tn}) within $MTree_{ps}$
To find the similarity between the items within the tree we created the graph using a hyperbolic tangent function as shown in Fig.2.
To find the similarity between the items within $MTree_{ps}$ we created the following logarithmic graph as shown in Fig.2. In order to evaluate the trust value within $MTree_{ps}$, this method suggests the following formula:

$$T_{tn(Final)} = T_{tn(level1)} + T_{tn(level2)} + ... + T_{tn(levelx)} \tag{2}$$

To find the trust value of every level $T_{tn(levelx)}$, this method suggests the following equation

$$T_{tn(level)} = \frac{N_{pc}}{N_{total}} * Dis_{level} \tag{3}$$

While N_{pc} is a number of a specific product sold in the specific level, N_{total} is a number of all products that have
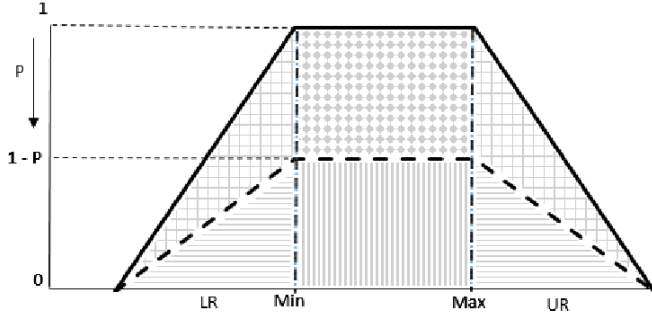
Fig. 3. the influence of transaction amount on trust value

been sold in the specific level and Dis_{level} is the distance between the levels which can be obtained by using the following formula:

$$Dis_{level(x)} = SIM_{level(x+1)} - SIM_{level(x)} \quad (4)$$

Where SIM_{level} is identified by using the hyperbolic tangent function as shown in Fig.2.

$$SIM_{level} = tanh(level) \quad (5)$$

2) TRUST EVALUATION METHOD BASED ON TRANSACTION AMOUNT SIMILARITY

Transaction amount is another important dimension which play an important role in the transaction context in order to establish a trustworthy relationship between two nodes in e-commerce environment. As shown in Fig.3,There are two scenarios in term of measuring the similarity between the new transaction amount and the past transactions amounts to evaluate the trust value.

1st Scenario: The new transaction is on selling a product that has been sold and it is in the seller products tree. In this case, there are some cases that are needed to be considered in order to evaluate the trust value in the transaction amount dimension.

The new transaction amount is in between the minimum and the maximum amount of the all transactions amounts that are made by the seller.

$$MIN \leq X \leq MAX; T_{AM} = 1$$

In this case, the similarity between the new transaction amount and the past transactions amounts will be considered as in the highest level. As a result, the trust value will be considered as the highest value which is ONE.

Case 1: The new transaction amount is less than the minimum amount in the past transactions. In this case this method suggests Lower Range (LR) which is %25 of the minimum amount of the past transactions. There are two scenarios can happen listed as follows:

a) The new transaction is in between the minimum amount and the lower range (LR).

$$LR(MIN) < X < MIN$$

In the case, the trust value between the transaction and the past transactions is identified as expressed in Equation 1

$$T_{AM} = \frac{x - min(1 - LR)}{min(LR)} \quad (6)$$

b) The new transaction is equal or less than the lower range of the minimum amount.

$$X \leq LR(MIN); T_{AM} = 0$$

In this case the trust value between the new transaction amount and the past transactions amounts will be considered as Zero because there is no similarity between them.

Case 2: The new transaction amount is higher than the maximum amount in the past transactions. In this case this method suggests Upper Range (UR) which is %10 of the maximum amount of the past transactions. There are two scenarios can happen listed as follows: a) The new transaction is in between the maximum amount and the Upper range (UR).

$$MAX < X < UR(MAX)$$

In the case, the trust value between the transaction and the past transactions is identified as expressed in Equation 2

$$T_{AM} = 1 - \frac{x - max}{max(UR)} \quad (7)$$

b) The new transaction is equal or higher than the upper range (UR) of the maximum amount.

$$UR(MAX) \leq X; T_{AM} = 0$$

In this case the trust value between the new transaction amount and the past transactions amounts will be considered as Zero because there is no similarity between them.

2nd Scenario:

The new transaction is on selling a product that has not been sold and it is not in the seller products tree. Although, there is a similarity between the new transaction amount and the past transactions amount, the trust value is less than ONE. The reason for that, the seller has not been in any transactions in selling this new product, so the trust value should be lesser than if the new transaction is made in the same product as well as the same amount. Additionally, as discussed in the last section, a seller can sell the same product in the same amount, so he/she should obtain the higher value than if he/she starts making a new transaction by selling different product or different amount. This method is to prevent this kind of problem which is the value imbalance problem. Therefore, the trust value should be decreased if the seller starts selling a new product or being in any transaction with different amount. As a result, in order to prevent this kind of problem, this method considers P

as a penalty of lacking the experience in selling the new product using the following formula:

$$P = 1 - SIM_{level}$$

(8)

Where SIM_{level} is a similarity which is obtained by using the hyperbolic tangent function as discussed in last section and shown in Fig.2.

There are some cases taken in account in order to evaluate the trust value discussed below:

Case 1:
The new transaction amount is in between the minimum and the maximum amount .

$$MIN \leq X \leq MAX; T_{AM} = 1 - P$$

In this case, the similarity between the new transaction amount and the past transactions amounts will be considered as in the highest level after applying P.

Case 2:
The new transaction amount is less than the minimum amount. In this case this method suggests Lower Range (LR) which is the percentage of the minimum amount. There are two scenarios can happen listed as follows: a) The new transaction is in between the minimum amount and the lower range (LR).

$$LR(MIN) \leq X \leq MIN$$

In the case, the trust value between the transaction and the past transactions is identified as follows:

$$T_{AM} = \frac{x - min(1 - LR)}{min(LR)} - P$$

(9)

b) The new transaction is equal or higher than the lower range of the minimum amount.

$$LR(MIN) \leq X; T_{AM} = 0$$

In this case the trust value between the new transaction amount and the past transactions amounts will be considered as Zero because there is no similarity between them.

Case 3: The new transaction amount is higher than the maximum amount. In this case, this method suggests Upper Range (UR) which is the percentage of the maximum amount. There are two scenarios can happen listed as follows:
a)The new transaction is in between the maximum amount and the Upper range (UR).

$$MAX < X < UR(MAX)$$

In this case, the trust value is identified as follows:

$$T_{AM} = 1 - \frac{x - max}{max(UR)} - P$$

(10)

b) The new transaction is equal or higher than the upper range (UR) of the maximum amount.

$$UR(MIN) \leq X; T_{AM} = 0$$

In this case the trust value between the new transaction amount and the past transactions amounts will be considered as Zero because there is no similarity between them.

IV. RESULTS AND DISCUSSION

Example 1: Assume that a seller is going to make a new transaction by selling Fax. Following the proposed method, Fax as a product is in the level four in $MTree_{ps}$, , so there are three factors need to be measured in level one, level two, level three as well as level four.

Factor 1: the number of product sold N_{pc} in every level which are 100 transactions in level one, 70 transactions in level two, 30 transactions in level three and 30 transactions in level four.

Factor 2: the Trust value in every level $T_{tn(level)}$ with measuring the distance Dis_{level} between the similarities in every level SIM_{level} as expressed in equation 4 . $T_{tn(level(1))} = 0.65$, $T_{tn(level(2))} = 0.175$, $T_{tn(level(3))} = 0.08$ and $T_{tn(level(4))} = 0.01$

Factor 3: the final trust value $T_{tn(final)}$ which is obtained by using the suggested formula as expressed in equation 2 so $T_{tn(Final)} = 0.915$ which is considered as a high value and this is because the seller has a good experience in selling Fax and he/she has sold all the required transactions in every level.

Example 2: Assume that a seller is going to make anew transaction by selling Laser Printer. Following the proposed method, Laser Printer as a product is in the level four in $MTree_{ps}$.

Factor 1: the number of product sold N_{pc} in every level which are 100 transactions in level one, 30 transactions in level tow, 30 transactions in level three and Zero transaction in level four.

Factor 2: tthe Trust value in every level $T_{tn(level)}$ with measuring the distance Dis_{level} between the similarities in every level SIM_{level} as expressed in equation 4 . $T_{tn(level(1))} = 0.65$, $T_{tn(level(2))} = 0.075$ $T_{tn(level(3))} = 0.08$ and $T_{tn(level(4))} = 0$ as no transaction has not been made in selling Laser Printer.

Factor 3: the final trust value $T_{tn(final)}$ wwhich is obtained by using the suggested formula as expressed in equation 2 so $T_{tn(Final)} = 0.805$ which is considered as a good value. Although, the seller has not made a transaction in selling this product, the product Laser Printer is still in his category as he sold 100 transactions in the same category which means he/she should be trustworthy in selling this type of product unless the amount of transaction has a big different which will be discussed in explaining the influence of the transaction amount dimension.

Example 3: Assume the seller is going to make a new transaction by selling something not in his category which means he/she has not sold before (lets say Tobacco). Following the proposed method, the seller has gained

$T_{tn(level)} = 0$ in the all levels in the tree as he/she has not made any transaction in this category which is completely different from his/her category. As a result, there is a big possibility for the fraud to be happened (the value imbalance problem), so the proposed method can prevent this kind of problem by giving the sellers final trust value $T_{tn(final)} = 0$ which means he/she is not trustworthy in selling this type of product.

In summary, the proposed method can be used to measure the similarity between the products types and the number of the product sold. additionally, in order to make this method more accurate, there is a huge need to add the transactions amounts as another dimension to it which has been discussed above. To clarify it, we used the last examples with this dimension (the transactions amounts). Assume that, the seller is going to make a new transactions in selling Laser Printer for £140. It can be seen that this product Laser Printer is not in the seller category as shown in Fig.1 and there is no transaction has been made in selling Laser Printer. The new transaction amount is £140 which is in between the minimum amount and the maximum transaction amount which were made in the level of Laser Printer. Following the proposed method, this transaction amount is expressed as $MIN \leq X \leq MAX$ as discussed above. However, this product Laser Printer is considered as a new product , so the proposed method suggests P as a penalty of lacking the experience in selling this new product which is expressed in equation 8. P = 0.02. therefore, the trust value of this new transaction amount of Laser Printer is less than ONE because this seller has not sold Laser Printer before but he/she has sold many products which are located in the same category of Laser Printer as shown in Fig.1. the trust value of this transaction amount $T_{AM} = 0.96$ after applying the penalty (P) due to the sellers lack of experience in selling Laser Printer. In order to evaluate the final trust value T_{Final} with the last examples by following the proposed method as expressed in equation 1, T_{Final} of selling Fax = 0.75 which is considered as Excellent as shown in the table I. the reason of that is the seller has made 30 transactions in selling Fax which obtains 0.915 in the first dimension T_{TN} but the new transaction amount of selling Fax is £260 is higher than his/her normal range in the same level four (Faxs level) which is (£50 - £250), so he/she obtains 0.6 in the transaction amount dimension (T_{AM}) which affects his/her T_{Final} value. In order to evaluate the final trust value T_{Final} with the last examples by following the proposed method as expressed in equation 1, T_{Final} of selling Laser Printer is 0.88 which is considered as Excellent as shown in the table I. Although, the seller has not made any transaction in selling Laser Printer, but he/she obtains 0.805 in the first dimension T_{TN}, this is because he sold many transaction in the same category of Laser Printer and the new transaction amount of selling Laser Printer (£140) is in the normal range in the same

TABLE I
RATING SCORES CATEGORIZATIONS

Poor	Medium	Good	Excellent
$0 \leq T < 0.25$	$0.25 \leq T < 0.5$	$0.5 \leq T < 0.75$	$0.75 \leq T \leq 1$

level four (Laser Printers level) which is (£50 - £250), so he/she obtains 0.96 in T_{AM}. Every e-commerce website has trust ratings scores which represents the final trust value of every seller. These scores are calculated using the given ratings by the buyers after every transaction. These scores are usually a set of numbers for example the rating scores which is in eBay [-1 ,0 ,1]. While epinions [2] shows the scores as an integer [0,1,2,3,4,5]. According to [20] the numerical values which is in 0,1 are more appropriate in order to evaluate the trust value. Therefore, this paper categorised the final trust value to five scales listed as shown in the table I:

V. CONCLUSION

In this paper, the proposed method is considered as a contextual trust evaluation method as it takes into account some contexts of any transaction (product type, number of product sold and transaction amount). This method can assist to prevent the value imbalance problem by measuring the similarity between three dimensions (contexts) and evaluating the final trust value. As a future work, there is a plan to implement this method and do the simulation by probably using a real data. There are more dimensions such as time to handle the transaction, the quality of the transaction need to be considered and added to this method in order to make it more accurate and reliable.

[2]http://www.epinions.com

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