Electrostatic Force Method: Trust Management Method Inspired by the Laws of Physics

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Abstract. Online auctions are among the most important e-commerce services. Unfortunately it is very difficult to assure trust in such customer-to-customer environment. Most auction sites utilize a very simple participation counts system for reputation rating. This feedback-based reputation systems do not differentiate between sellers who trade in luxury goods and those who sell worthless trinkets. A fraudster can easily gain reputation by selling hundreds of cheap books and then cheat while selling a few expensive TV sets which are not as good as described on item page.

In this paper we present a novel trust management method called *Electrostatic Force Method* (EFM) which calculates *Personal Subjective Trust* instead of overall reputation value. The trust value depends on price and category of an item one wants to buy. In this method a seller could have high trust value for someone who wants to buy a book and at the same time this seller may not be trustworthy for someone who wants to buy a TV set. Furthermore our method can be applied in addition to the system currently used by eBay-like online auction sites because it does not require any additional information other than positive, negative or neutral feedback on transactions.

Keywords: online auction sites, reputation system, trust management method.

1 Introduction

Statistics (see [18,15]) show that hundreds of millions of people are using online auction sites like eBay[17], Taobao[19] and Allegro[16]. Obviously these sites give a great opportunity to traders who can choose from a vast number of offers and meet millions of potential customers. Online transactions, however, are a bit more dangerous than traditional ones due to the anonymity of portal users. Furthermore, the majority of popular auction sites use the same very simple trust mechanism in which the credibility of a user is the number of positive feedbacks minus the number of negative ones. This mechanism is insufficient in many aspects. Firstly, reputation of a buyer and reputation of a seller is treated equally.

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Overall reputation score combines information of feedbacks gained after buys and sells, so one needs to study detailed information about potential traders to check if she/he has gained reputation by buying or selling[1]. Secondly, buyers are often hesitant to give negative feedback for fear of retaliation if the seller is a huge online store (on which a single feedback has virtually no effect) and occasional buyer (with only a few reputation scores) does not want to get any negative feedback. Thirdly, in existing reputation system it is impossible to check what kind of sold item is represented by a feedback and how expensive it was. Existing reputation systems create some kind of Simpson's paradox[11], because information about a seller who trades with luxury goods and worthless trinkets is aggregated into a single reputation value. It is unlikely for anyone to buy a TV in a grocery shop in non-virtual environment, whereas it is rather common situation in online auctions. Let us consider a hypothetical seller *Cut-Me-Own-Throat Dibbler* who has gained high reputation score by selling 400 *"lucky amulets that bring good health"* for 3 euros each and then starts acting dishonestly. After selling every four or five cheap amulets he sells one expensive TV set which is not exactly *"new and in good condition"* for 500 euros. This so called "accumulation" fraud is an increasing problem (see [7,3] for example). In the existing system, *Dibbler* will constantly gain increasing reputation score as long as he gets positive feedback for more than half of transactions.

We argue that the best solution for the problems discussed above is to replace the overall reputation value with Personal Subjective Trust (PST) evaluated by Electrostatic Force Method. The trust for a seller should by different depending on what a buyer wants to buy. In the above example *Dibbler* is trustworthy from the point of view of someone who wants to buy a lucky amulet but at the same time Dibbler is not trustworthy for someone who wants to buy a TV set.

Moreover we do not have to change the way users rate each other. A great advantage of the trust system currently used by eBay, Taobao, Allegro and other auction sites is the simplicity of use. We do not intend to confuse users with sophisticated method of rating but we want the item page to show PST evaluated by EFM in addition to overall score currently used. That solution will allow buyers to quickly and easily asses credibility of sellers, most importantly their credibility in contex of selling the particular kind of item.

2 Related Work

The Feedback Forum used by most auction sites (like [17,16,19]) is perhaps best known example of rating system. It is impossible for a buyer to read all the textual comments associated with all potential sellers' previous transactions, therefore auction sites sum up all positive comments and substract all negative ones and present it as a single reputation score. This system has many drawbacks (see also [5,12,2]). Many researchers presented trust algorithms and metrics

[1] Overall reputation score is shown next to user's name on every item page so it is visible at a glance, whereas details about feedbacks are visible only on user's information pages.

based on more sophisticated reputation functions to quantify trust, for example classic algorithm SPORAS [13] and PeerTrust model [12]. These algorithms use a *consensus-based function* i.e. all system's users agree how trustworthy is every particular user. Our previously presented Asymptotic Trust Algorithm (ATA) [4] can be implemented along with the commonly used trust system and provide some useful information about user's reputation history but it is also consensus-based.

Some scientists (e.g. [1]) suggest that the trust of a user cannot be presented as a single global value and depends on who is asking for the trust value. Algorithms like HISTOS [13] or RRM [14] based on the principle: *If A trust B and B trust C, then A should trust C to some extend.* However others (like for example Marsh [6]) pointed out that trust is not transitive.

Unfortunately above methods do not deal with the Simpson's paradox mention in the Introduction, because they aggregate user's reputation to a value/score regardless of the situation in which one is asking for trust. Furthermore most of these solutions are difficult to introduce into existing auction systems because they change the way user interact.

Most scholars realised that negative feedbacks are very rare (see [4,10,9]). Mainly because buyers are often hesitant to give negative feedback for fear of retaliation. [8] presented an interesting idea how to deal with *implicit feedbacks* but a simpler way is to treat sellers' reputation differently and more carefully.

3 Electrostatic Force Method (EFM)

3.1 Definitions and Metaphor Based on the Laws of Physics

EFM is inspired by *Coulomb's Law* describing the electrostatic interaction between charged particles. In EFM feedbacks gained by a seller are represented by *Feedback's Charges* q in 3-dimensional Euclidean space, called *Reputation Space* – Figure 1. Positive electric charges q^+ represent positive feedbacks, negative electric charges q^- represent negative feedbacks and neutral feedbacks do not change reputation therefore are not represented by charges. When a transaction is made and a feedback is given, a new Feedback's Charge is located in the Reputation Space. Price and category of sold item determine the position of the charge. Once put particles can not move, they are fixed in the Reputation Space. Coordinates of Feedback's Charge are:

- The z coordinate is constant $q_i z = 0$, charges are placed only on the xy plane.
- The x coordinate represents the price of the sold item $q_i x = \log_2(price_i)$. We use $\log_2$ to “smoothly” differentiate items by their prices. We have assumed that when feedbacks are compared the distance between feedbacks related to an item for 10€ and an item for 20€ should by the same as the distance between feedbacks related to an item for 100€ and an item for 200€.
- The y coordinate represents the category of the sold item. There is a certain distance between each pair of categories, for example *Computers* and *Electronics* are similar therefore these categories are relatively close to each

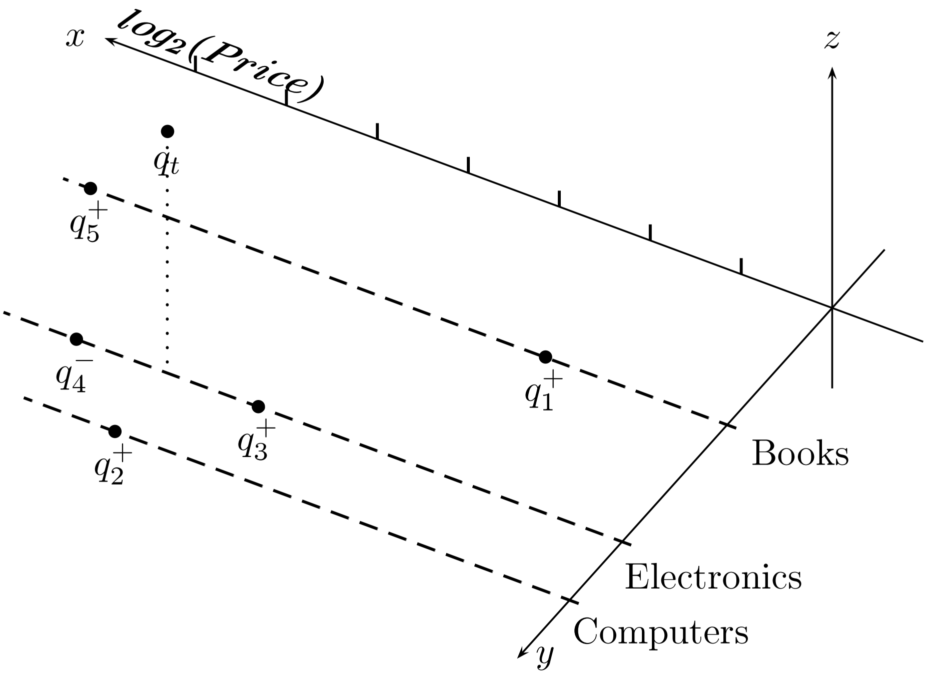

Fig. 1. Reputation of a seller

other. Auction portal administrators may freely define distances between categories, so it may be impossible to arrange a lot of categories on one axis but this is only a metaphor and EFM does not need the position in y-dimension to evaluate trust but only requires distances $\varDelta y_{ab}$ between each pair of (a, b) categories. In particular the distance between categories may be defined as

$$\varDelta y_{ab} = \begin{cases} 0 & \text{if } a = b \\ constant > 0 & \text{if } a \neq b \end{cases}$$

Instead of a single reputation value a buyer evaluates an item dependent trust value. To evaluate seller's trust a *Trust Test Charge* q_t (a negatively charged particle $q_t = -1C$) is placed in the Reputation Space and Coulomb force is calculated. The location of the Trust Test Charge is determined by price $(q_t x)$ and category $(q_t y)$ of the item the buyer wants to buy and certain (arbitrarily chosen) location in z-dimension $q_t z$. The z-component of Coulomb force vector represents the seller's trust, i.e. the stronger the Test Charge is pulled toward the xy plane (plane with all charges representing feedbacks) the more trustworthy is the seller.

The electrostatic force is inversely proportional to the square of the distance between charged particles. Due to this property the item dependent trust value is highly influenced by feedbacks related to items from the same or similar category and similar price.

In the simplest implementation each particle has the unit charge (for example one coulomb $q^+ = 1C$ and $q^- = -1C$). However it may be desired to treat old feedbacks as less important – this can by easily achieved by decreasing the charge in time. Every feedback puts a new particle with a maximum charge and then the charge starts "fading" slowly until it disappears completely after a long time. It is also possible to build a system with more options for feedback provider by allowing users to use charges of different strength to indicate different levels of satisfaction or dissatisfaction. For example, we can easily adopt EFM to 5-star rating system[2].

3.2 Example

Figure 1 show an example of a seller's reputation. The seller sold the following items:

- A cheap book for 4€ and gets positive feedback for this transaction (q_1^+).
- A computer part for 32€, gets positive feedback (q_2^+).
- A piece of electronics for 16€, gets positive feedback (q_3^+).
- A piece of electronics for 64€, gets negative feedback (q_4^-).
- A very rare and expensive book for 128€, gets positive feedback (q_5^+).

Assume that a buyer wants to buy an MP3 Player for 32€ from the seller. The Figure 1 shows Trust Test Charge q_t over the Electronics category over the place on the xy plane where potentially a Feedback's Charge would be located for this transaction if the feedback will by given.

3.3 Formulas

According to the Coulomb's Law, the force exerted on Trust Test Charge q_t by charged particle q_i is defined as:

$$\vec{F} = kq_t \frac{q_i}{r_i^2} \hat{r}_i$$

where r_i is the distance (between q_t and Feedback's Charge q_i) and $\hat{r_i}$ is a unit vector pointing along the line from q_i to q_t. k is called "Coulomb force constant" (or "the electric force constant") and in real physical world is defined to be $k = 8.99 * 10^9 \frac{Nm^2}{C^2}$ but in our system it is just a scaling factor.

The principle of linear superposition may be used to calculate the force on the Trust Test Charge due to a set of n Feedback's Charges:

$$\vec{F} = \sum_{i=1}^{n} \vec{F}_i$$

[2] 5-star rating system is used by eBay as Detailed Seller Ratings. A buyer can rate: accuracy of item description, communication, delivery time and postage & packaging charges.

The unit vector $\hat{r_i}$ may be calculated using simple geometry:

$$\hat{r_i} = \frac{\Delta x_{it}\hat{x} + \Delta y_{it}\hat{y} + \Delta z_{it}\hat{z}}{r_i}$$

where $\hat{x}$, $\hat{y}$ and $\hat{z}$ are unit vectors directed along the positive axes a, y and z respectively. Δx_{it} is the difference of positions in the x-dimension between the i-th Feedback's Charge and the Trust Test Charge, defined as $\Delta x_{it} = (q_i x - q_t x) = (\log_2(price_i) - \log_2(price_t))$. Δy_{it} is the distance between category of Trust Test Charge and category of i-th Feedback's Charge (distances between each pair of categories are defined arbitrarily). Δz_{it} is the difference of positions in the z-dimension $\Delta z_{it} = q_i z - q_t z$. All the Feedback's Charges are placed on the xy plane (always $q_i z = 0$) and $q_t z = constant > 0$, therefore $\Delta z_{it} = -q_t z$. And the distance between Trust Test Charge and i-th Feedback's Charge is defined as:

$$r_i = \sqrt{\Delta x_{it}{}^2 + \Delta y_{it}{}^2 + \Delta z_{it}{}^2}$$

We defined the Personal Subjective Trust of a seller as the force that pulls toward the xy plane therefore to calculate trust PST we need only the magnitude of the z-component of the force vector:

$$|\hat{z_i}| = \frac{\Delta z_{it}}{r_i}$$

EFM defines Personal Subjective Trust of a seller as:

$$PST = kq_t \sum_{i=1}^{n} \frac{q_i}{r_i^2} |\hat{z_i}|$$

$\Delta z_{it} = -q_t z$ and q_t is a negative charge $q_t = -1$ so we do not need to use vectors to calculate trust and instead use the formula:

$$PST = kq_t z \sum_{i=1}^{n} \frac{q_i}{r_i^3} \tag{1}$$

PST needs to be calculated in three cases: when an auction is started, in case of new bid (change of price) and when the seller gets a new feedback (in this case the whole sum do not need to be calculated again, only one component is added to previous PST value). Time complexity of this algorithm is O(n) (where n is the number of feedbacks received by the seller). We implemented PST method in C#, and observe that standard desktop computer with Pentium 4 processor needs less than 0.01s to calculate PST for a seller with more than 100000 feedbacks therefore our method will not overload auction portals' servers.

4 Experimental Evaluation

To verify if EFM meets our expectations we performed a series of experiments. We used synthetic datasets to observe how the calculated trust value will differ in certain circumstances. Gathering real data from auction site allows us to make sure that EFM is useful.

4.1 Verifying the Principles

Firstly let us test the behaviour of EFM in case of extremely simple situation to demonstrate and verify the principles. Figure 2a shows a Reputation Space of a seller who sold one item for 4€ and one item for 1024€ and got positive feedbacks for this transactions. Figure 2b shows a Reputation Space of a different seller who also sold one item for 4€ and one item for 1024€, but this seller got negative feedback for the expensive item. A buyer wants to buy an item for 64€ (also from the same category) so Trust Test Charge is placed in both Reputation Spaces to evaluate and compare sellers credibility. For the sake of clarity every item belongs to the same category and Figure 2 does not present the y-dimension. In this experiments we used the following parameters: $q_t z = 4$ and

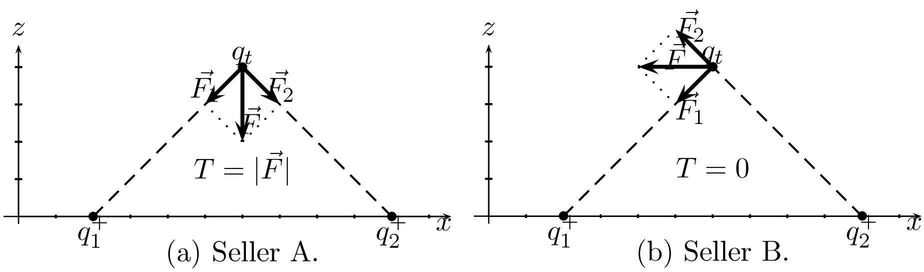

Fig. 2. Evaluating credibility of sellers with only 2 feedbacks in only one category

$k = 32$ (with this parameter's values length of vectors on the figures represents their magnitude). We can use Formula (1) to calculate Personal Subjective Trust: For seller A: $PST = 32 * 4 * (\frac{1}{\sqrt{4^2+0^2+4^{2^3}}} + \frac{1}{\sqrt{4^2+0^2+4^{2^3}}}) = \frac{2}{\sqrt{2}} \approx 1.414$ And for seller B: $PST = 32 * 4 * (\frac{1}{\sqrt{4^2+0^2+4^{2^3}}} + \frac{-1}{\sqrt{4^2+0^2+4^{2^3}}}) = 0$ As we can see negative and positive feedbacks neutralise each other and positive ones adds up so the basic requirement is met.

Let us use the same sellers to demonstrate how the trust looks from different points of view. Imagine buyers who wants to buy 7 different items (in particular it might by a single buyer who wants to buy 7 items at once). When a buyer enters an item page he/she sees trust value of the item's seller. With EFM presented trust value will be also different for different items. Figure 3 and related Table 1 show 7 different evaluations (7 different Trust Test Charges)

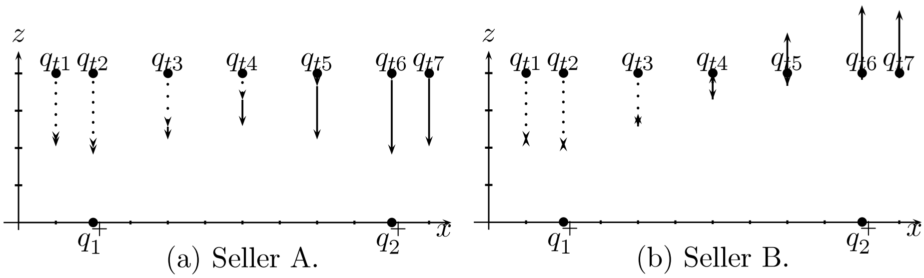

Fig. 3. Evaluating credibility in cases of 7 different items to buy

Table 1. Values of trust from the perspective of 7 different items

	q_{t1}	q_{t2}	q_{t3}	q_{t4}	q_{t5}	q_{t6}	q_{t7}
Item price	2	4	16	64	256	1024	2048
PST: seller A	1.960	2.179	1.772	1.414	1.772	2.179	1.960
PST: seller B	1.692	1.821	1.090	0.000	-1.090	-1.821	-1.692

Table 2. Δy distances between categories

	Computers	Electronics	Phones	Books	Others
Computers	0	2	4	6	10
Electronics	2	0	2	4	8
Phones	4	2	0	4	6
Books	6	4	4	0	4
Others	10	8	6	4	0

related to 7 items with different prices (again items are from the same category for the sake of clarity).

Figure 3 shows only z-component of forces. Sum of the z-component of forces between the Trust Test Charge and Feedbacks' Charges is the Personal Subjective Trust evaluated by EFM whereas x and y components of Coulomb's force do not influence trust value. Dotted lines represent the z-component of forces between Test Charge and feedback q_1 and solid lines represent the z-component of forces between Test Charge and feedback q_2. This simple experiment demonstrates that credibility of a seller depends not only on the number of gained positive and negative feedbacks but also depends on the kind of sold items related to these feedbacks. Ignoring the fact that history containing only two feedbacks is insufficient to asses seller in any case, we can see that seller B is quite reliable (has good history) in case of unexpensive item but is untrustworthy in case of expensive ones.

To perform further experiments we had to define distance (Δy) between each pair of categories. Table 2 presents distance we have chosen to perform our experiments. These values are based on our intuition (for example phones are similar to electronics so distance between this categories is small) but of course they may be defined differently. Now we can calculate PST for the example presented in subsection 3.2 (and Figure 1): $PST = 32 * 4 * (\frac{1}{\sqrt{3^2+4^2+4^2}^3} + \frac{1}{\sqrt{0^2+2^2+4^2}^3} + \frac{1}{\sqrt{1^2+0^2+4^2}^3} + \frac{-1}{\sqrt{1^2+0^2+4^2}^3} + \frac{1}{\sqrt{2^2+4^2+4^2}^3}) \approx 2.511$

4.2 Real Dataset

To examine real life use case we used transaction history of certain Allegro users. Figure 4 presents feedbacks gained by two sellers between 20th February and 1st March 2011[3]. Let us consider a buyer who wants to buy a certain phone accessory,

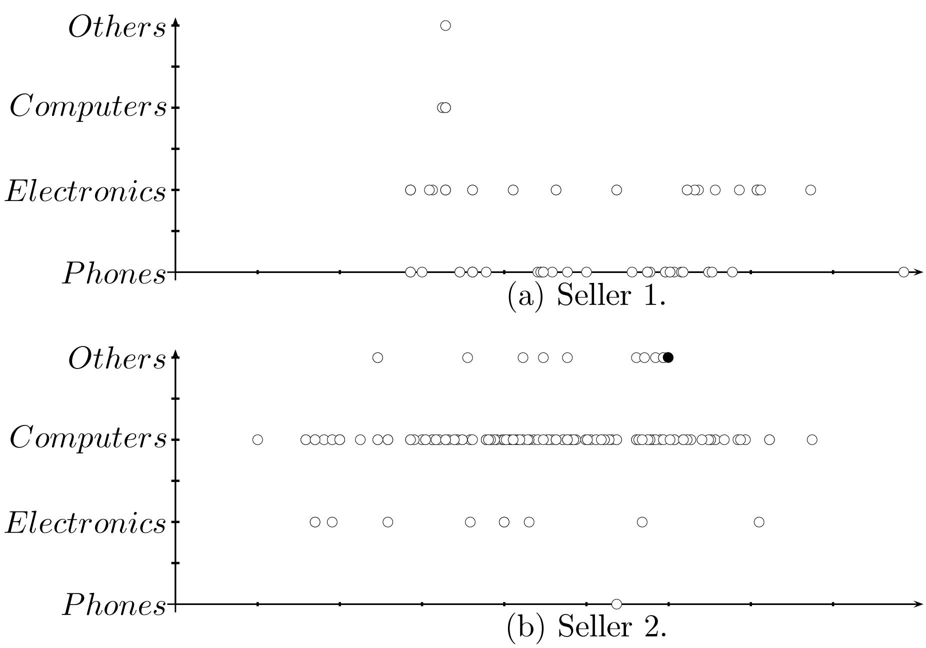

Fig. 4. Reputation Space of two sellers from the point of view of someone who wants to buy from Phones category

both sellers offered it for 41.25€ [4]. The y-axes on both Figure 4a and Figure 4b represent Feedback's Charges distances from Phones category i.e. figures show Reputation Spaces of these two sellers from the point of view of someone who wants to buy an item from category *Phones*. The x-axes is related to sold items

[3] On Allegro detailed information are available only for recent transaction, so we will consider only small part of sellers history. To perform this experiment we chose sellers who sold a lot of items in that short period of time.

[4] Assuming exchange rate in March 2011: 1€ = 4PLN.

prices ($q_i x = \log_2(price_i)$). Each empty circle on the figure represents one positive feedback. In our dataset there is only one negative feedback – the black circle on Figure 4b in category "Others".

Seller 1 gained 87 positive feedbacks and Seller 2 gained 198 positive feedbacks and 1 negative so in the currently used reputation system during chosen time they score 87 and 197 respectively. As we can see the Seller 2 gets over twice the points as the Seller 1 but most of Seller's 2 feedbacks are related to Computers category. He/she sells a lot of computers, computer parts and accessories but only occasionally something from Phones category. Seller 2 on the other hand is specialised in Phones and Electronics.

Using the same parameters as before, i.e. $q_t z = 4$, $k = 32$ and distances from Phone category from Table 2 we can calculate Personal Subjective Trust for both sellers:

- Seller 1: $PST = 121.1$
- Seller 2: $PST = 126.5$

As we can see, in this case sellers are almost equally trustworthy. We would like to point out that values of parameters that we have chosen assure that PST value is in the same scale as currently used reputation score. This experiment shows that buyer will be able to easily compare PST value with reputation score currently used. PST slightly greater (like in case of Seller 1) indicates that the seller trades mostly in items similar to the item the buyer wants to buy. In case of Seller 2 PST is smaller than simple feedback count because he/she sells a lot of items from different categories. Auction sites users may accept new measure easier if its values will be similar to the one currently used.

4.3 Impact of Parameter Settings

Let us now examine how the trust value evaluated by EFM will differ if we change Trust Test Charge position in z-dimension. Table 3 presents PST value of the same two sellers from the point of view of a buyer who wants to buy the same phone accessory for 41.25€ but in case of differently defined $q_t z$ parameter. For better illustration we have adjusted the k scaling factors in such a way that

Table 3. PST value for different $q_t z$ parameter

$q_t z$	1	2	4	8	32	100
PST: Seller 1	587.385	297.897	121.115	38.591	2.695	0.278
PST: Seller 2	113.562	132.933	126.537	66.818	5.985	0.629

PST of Seller 1 is equal to his/her feedback count, Table 4 presents the results. As we expected the lower the values of $q_t z$ the more favoured will be the sellers who trade in items very similar to the item the buyer wants to buy. If $q_t z$ value is very height, EFM produces results similar to simple feedback count systems used currently.

Table 4. PST value for different $q_t z$ and k parameters

$q_t z$	1	2	4	8	32	100
k	4.740	9.346	22.986	72.142	1032.865	10008.923
PST: Seller 1	87	87	87	87	87	87
PST: Seller 2	16.820	38.823	90.894	150.637	193.185	196.602

5 Conclusion

In this paper we have presented a novel approach to trust management in online auctions. Feedback-based reputation systems currently used by auction sites and algorithms presented in literature aggregate trust and ignore the context of item's price and category. This creates kind of Simpson's paradox. Many of these algorithms of course take price into account when calculating reputation score but they simply treat expensive items as more important (which is not always the case) and "flatten" trust to a single value. One can easily imagine a seller who is very thorough and helpful when selling a TV and does not care when selling small potatoes. We believe that Electrostatic Force Method is the first method that deals with this Simpson's paradox and is still easy to use and understand from users' point of view. The presented method shows sellers in different light depending on what kind and how expensive item one wants to buy because one seller may be more trustworthy when one wants to buy a TV and other may be better in case of book sales.

EFM is focused on sellers' reputation because the success of a transaction depends mostly on seller's honesty. A buyer who usually sends money before getting the product takes a great risk, whereas a seller might easily cheat by selling items which have some hidden failures or are second-hand instead of new. A buyer simply does not get the product if she/he does not pay, so it is very unlikely that a buyer will cheat. Treating sellers differently assures that buyers will not hesitate to submit a negative feedback when necessary, which may be the case in currently used system, because of buyers' fear of retaliation.

In our opinion the best complex solution for reputation system in auction sites is to combine our previous ATA algorithm [4] and EFM with existing feedback-based reputation system. Both ATA and EFM were designed to utilize feedback information currently available on auction sites, we do not need to confuse users with different methods of rating transactions. An item page may present the value calculated by EFM which describes sellers trust in context of this particular item.

In our future work we consider extending this mechanism to buyers' reputation. We want also to adapt our method to work with 5-star rating system used by eBay and similar auction sites as Detailed Seller Ratings. Even more promising seems to be the version of EFM where ratings decrease gradually to make old transactions less important, i.e. new rating puts a maximum (positive or negative) charge and then the charge starts "fading" slowly until it disappears completely. We would like also to find different applications for

EFM not only in e-commerce but also other multi-agent systems. Such reputation mechanism may be useful in all kinds of discussion forums and recommendation systems.

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