Trust-Based Multi-stakeholder Decision Making in Water Allocation System

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Abstract. Water allocation domain requires collaboration among stakeholders when making any decision regarding the solution to use to get the maximum benefits with fewer damages. The challenging part of the water allocation system is the interactions among those entities with the existence of conflicts. Therefore, there has to be a decision-making model that takes the stakeholders into account when producing the best outcomes. Due to the involvement of people who make the decision, trust among them comes to the picture. Moreover, every solution is associated with a number of benefits and damages. Trust is used as primary criteria in decision-making model along with the damages and benefits associated with each solution. The main contribution of this paper is to build a multi-stakeholder Decision-Making Model having these characteristics: trust, damages, and benefits as criteria, trust is associated with the involvement of the human. The model is dynamic by adapting to the changes over time. The decision to select is the solution that is fair with almost everyone.

1 Introduction

In this paper, we propose decision-making model for Water Allocation system to help the participants to be able to select the solution comes from the best model. Several criteria involved when deciding on the model to choose such as Trust, Damage, and Benefit. The preferred scenario is when having a high trust, low damages, high benefits. The worst scenario is when having a low trust, high damage, and low benefit. Before discussing the computation of these criteria, it is important to introduce the entities and their attributes. The proposed model has many types of entities: organization, expert, model and the decision.

Our view about the problem domain involves a network of experts, and each one of them has an assigned trust value based on several factors such as interactions and the level of experiences. There are also a set of models with assigned trust value which is associated with the error of the model. Each proposed solution has benefits and damages. An important point to mention here is that the quantification of the trust is based on the management theory. We have proposed a trust model trust system [9,32–37,48]. This trust model has three stages:

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trust modeling, trust management, and decision making. The quantification of the trust has been taken care of in the trust modeling and management phases. The value comes out of the trust management phase will be applied in the decision stage (Fig. 1).

When the project starts, each expert proposes a solution about the amounts of water to divide among everyone. The system will filter out the model according to the extreme damages. Therefore, the model with extreme damages will be excluded from the selection. The result is a subset of models. Then Each expert rates the proposed solutions as well as rates other experts to model the trust. Since each model is associated with damages, then such damages lead to a risky decision.

As it can be seen, this decision-making model can be described as collaborative and dynamic one. Collaborative because it is a group decision making, dynamic because it adapts to the changes over time.

In this paper, we will list the existing works in Sect. 2. Then, in Sect. 3, we will address the trust and describe its meaning to the problem domain. In Sect. 4, we list some possible ways of ratings and explain them by examples. In Sect. 5, we present our proposed Multi-stakeholder Decision Making based on Trust. We apply the proposed model to a scenario in Sect. 6. Finally, we conclude the paper and show the future direction in Sect. 7.

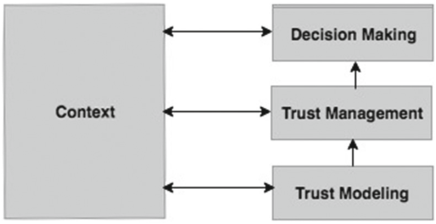

Fig. 1. Trust Framework which has three phases, each phase depends on the previous one

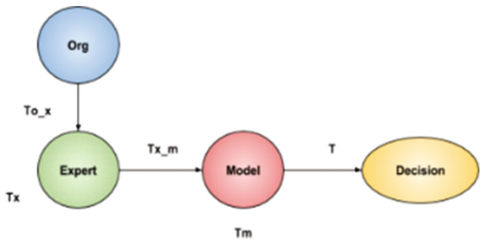

Fig. 2. Trust chain among entities in the Water Allocation system

2 Related Work

There are several works related to decision-making while using the trust as criteria. These works are different in term of trust model and decision-making technique. By analyzing the existing works, we may classify the decision-making techniques to algorithmic, policy, MCDM (Multicriteria Decision Making) approaches.

Trust as decision criteria has been applied to many existing works in different applications such as e-banking environment, [2], online social networks [21], multi-agent system world [3,29], access control [5,11,12,24,26], economy [22], p2p (peer to peer) [13,15,17,20,25,38,43,47,49], mobile payment [27,28], voting [46], cloud computing [7], cyberspace applications [8], spam detection application [10], mobile interaction applications [30], general application [19]. In term of group decision making using trust, several works were proposed in different fields. [1,4,6,18,23,31,39–42,44]. In term of making the decision about Fragmentation-Free Land Allocation with multi-stakeholder, [45] proposed work and it has been stated that "We introduce three frameworks for land allocation planning, namely collaborative geodesign, spatial optimization and a hybrid model of the two, to help stakeholders resolve the dilemma between increasing food production capacity and improving water quality". [14] has proposed a multi-stakeholder framework for urban runoff quality management and showed results by using three methods of negotiations such as a non-cooperative game, Nash model and social choice procedures.

3 Trust

Trust is a result of meeting expectation and reaching a level of satisfaction toward other entities in particular context. Therefore, there is no universal definition of trust since it is context-dependent. In general, we formulate a trust toward other entity based on our interaction with them or the level of knowledge in the case of human and the reliability in case of a model. The factors which are corresponding to the interaction and model reliability depends on the context. Figure 2 shows the chain of the trust assigned to the entities in our problem domain. In the chain, there is a trust between organization and expert, To_x. There is a trust assigned to expert based on some criteria contributes to human trust, Tx. There is also a trust from the expert given to the model Tx_m. The model also has its trust. The result of the chain of the trust is a final trust value T which contributes to the decision-making criteria. Each expert is assigned a trust value based on others judgment toward him; we call it human trust. This kind of trust is between the humans in the human networks. It can be quantified by the Social communications between members, Experience, Background, Number of years of Experience, Profile similarity and Friendship. There is also a trust relationship between experts and models; we call it Human-to-Model Trust. This kind of the trust is the one given to the model by the human. It can be quantified by the frequency of using the model and model ratings. There is also trust related to the

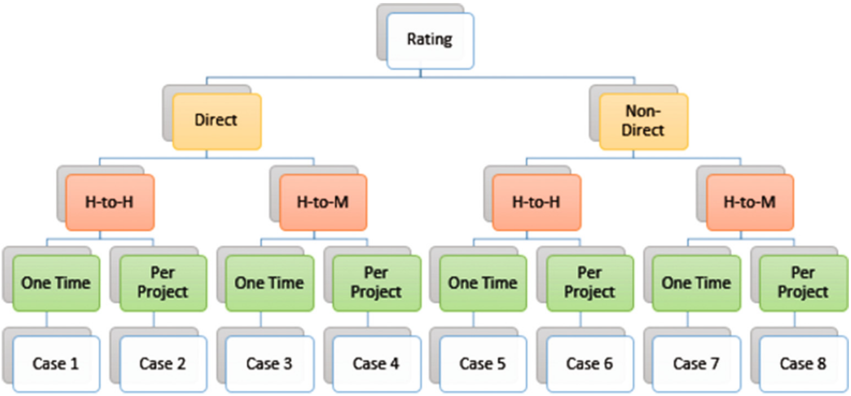

Fig. 3. Rating hierarchy structure which involves Direct and non-direct rating as well as Human to human and Model to Model ratings (H-to-H, H-to-M). Some ratings are given during the project and some are not (Per Project, One Time).

model, but without human judgment, we call it Model Trust. It is helpful because it contributes to the error of the model. Therefore, the factor that quantifies this value is the reliability of the model.

4 Possible Cases of Rating

The possible cases are shown in Fig. 3. The rating has been first classified to Direct and Non-Direct. Next, each class is classified according to the rating target, Human or Model knowing that the source of the rating is always human. Then each class is further classified according to the relevancy to the project, One time or Per Project.

The following are the criteria to rate about human and model. Some of these criteria depend on the project (Per Project), and some are not (One Time):

– Human Criteria (One time): Years of Experience and Friendships.
– Human Criteria (Per project): Model Selections.
– Model Criteria (One time): Reliability.
– Model Criteria (Per project): Benefits, Damages, and Outcomes.

5 Multi-stakeholder Decision Making Based on Trust

Knowing that there are different approaches to decision making is very helpful when building a decision-making model. In our view, the decision-making model is based on a particular algorithm we design (Algorithm 1). Additionally, the rules and policy approach will also be used in case of having group decision making to restrict the decision makers to the predefined policies like the

Algorithm 1. Solution Selection Algorithm based on Trust

procedure SELECTSOLUTION
    $S = getStakeholders()$
    $Soutions = selectSolutions()$
    $Damages = ComputeDamages(Solutions)$
    $Benefits = ComputeBenefits(Solutions)$
    $Utilities = ComputeUtilities(Damages, Benefits)$
    each Si rate solution Mj
    $T = calculateTrust(S, M)$
    $Fairness = Jain(Utilities, numberofstakeholders)$
    $weightedFairness = WF(Fairness, T)$

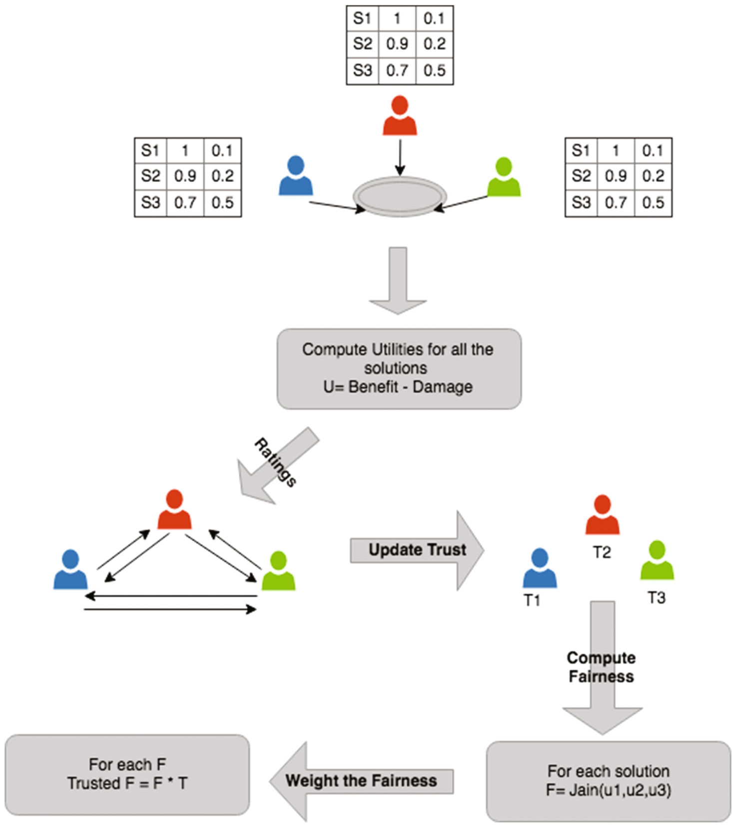

Fig. 4. System workflow which has several steps. It starts with proposing solution and the associated benefits and damages. Then, computing utilities, rating solutions, updating trust network and computing fairness for each solution

maximum total amount of water to allocate. So, our decision-making model is a combination of these approaches we surveyed. The ultimate goal is to select a model with less damage and high benefit. This ultimate goal is easy to find for an individual stakeholder. However, with multi-stakeholder, it is challenging. Therefore each stakeholder computes the fairness of his solution to estimate his solution fairness to the others.

Figure 4 shows the system workflow of this decision-making model. There are several steps. First, each stakeholder calculates the damages and benefits of the solution they choose to use those damages and benefits to compute the utilities. Then, the utilities are computed by subtracting the damages from the benefits corresponding to the stakeholders for each solution. Next, each stakeholder rates the others about their proposed solutions to show whether he agrees or not with the solution. As a result, the trust value of each stakeholder is updated based on our existing trust system [9,32–37,48]. After that, each stakeholder computes the fairness to guarantee that is everyone happy with the amount to take. The fairness formula is proposed by Jain [16] (Eq. 1). Finally, Weigh the fairness calculated by the corresponding Trust value. If the stakeholders agree with a particular solution due to the best trusted-fairness then, this solution is selected. Otherwise, the stakeholder enters another round repeating the same steps but with new solutions.

$$Jain(x_1, x_2, ..x_n) = \frac{(\sum_{i=1}^{n} x_i)^2}{n * \sum_{i=1}^{n} x_i^2} \tag{1}$$

6 Experiment and Result

In this section, we are going to apply the proposed solution to a water allocation by giving a scenario consists of two rounds.

6.1 Round 1

To simulate the water allocation scenario for the first round, we assume that three stakeholders have conflicts. These stakeholders have assigned trust value based on historical interaction and their profiles. Table 1 shows this kind of information.

Table 1. Round 1, List of stakeholders and the corresponding trust values

Stakeholder	Trust value
David	0.9
Steve	0.8
John	1

Then, each one of them proposes a solution which is an amount of water to share with other stakeholders. Tables 2, 3 and 4 shows the solutions proposed by David, Steve and John respectively.

Table 2. Round 1, The solution proposed by David showing the percentage of water for each stakeholders and the corresponding benefit, damage and the calculated utility which is the damage subtracted from the benefit

Stakeholder	Water percentage	Benefit	Damage	Utility
David	50%	1	0.1	0.9
Steve	20%	0.9	0.2	0.7
John	30%	0.7	0.5	0.2

Table 3. Round 1, The solution proposed by Steve showing the percentage of water for each stakeholders and the corresponding benefit, damage and the calculated utility which is the damage subtracted from the benefit

Stakeholder	Water percentage	Benefit	Damage	Utility
David	40%	0.9	0.1	0.8
Steve	30 %	1	0.1	0.9
John	30%	1	0.2	0.8

Table 4. Round 1, The solution proposed by John showing the percentage of water for each stakeholders and the corresponding benefit, damage and the calculated utility which is the damage subtracted from the benefit

Stakeholder	Water percentage	Benefit	Damage	Utility
David	40%	0.9	0.1	0.8
Steve	25%	1	0.2	0.8
John	35%	1	0.1	0.9

After this step, the stakeholders start rating each other. Table 5 shows the rating details. The rating is a 5-star system, five is the best, and one is the worst. Based on the above ratings, the trust of each stakeholder is changed. So, it is going to be 0.8, 0.9 and 1 for David, Steve, and John. After updating the trust value, the fairness index is quantified using the utilities computed by each stakeholder. The fairness index is calculated according to Jain's fairness index using Eq. 2.

$$F = \frac{(\sum_{i=1}^{n} u_i)^2}{n * \sum_{i=1}^{n} u_i^2} \tag{2}$$

Table 5. Round 1, Rating values from each stakeholders to others about the solutions proposed. This value contributes to updating the trust value for each participant

Stakeholder	Trust value	Stars
David	Steve	5
David	John	5
Steve	David	1
Steve	John	5
John	David	1
John	Steve	5

Table 6. Round 1, The solution proposed by John showing the percentage of water for each stakeholders and the corresponding benefit, damage and the calculated utility which is the damage subtracted from the benefit

Stakeholder	Fairness	Trusted Fairness
David	0.805	0.64
Steve	0.818	0.73
John	0.996	0.996

where U is the utility. Table 6 shows the computed fairness index for each proposed solution.

Finally, the stakeholder decides on which solution to take by considering the maximum trusted-fairness index. If they do not agree then they repeat the above process until they decide on a solution.

6.2 Round 2

Table 7 shows stakeholders and the assigned trust value.

Then, each one of them proposes a solution which is an amount of water to share with other stakeholders. Tables 8, 9 and 10 shows the solutions proposed by David, Steve and John respectively.

After this step, the stakeholders start rating each other. Table 11 shows the rating details. The rating is a 5-star system, five is the best, and one is the worst. Based on the above ratings, the trust of each stakeholder is changed.

Table 7. Round 2, List of stakeholders and the corresponding trust values

Stakeholder	Trust value
David	0.8
Steve	0.9
John	1

Table 8. Round 2, The solution proposed by David showing the percentage of water for each stakeholders and the corresponding benefit, damage and the calculated utility which is the damage subtracted from the benefit

Stakeholder	Water percentage	Benefit	Damage	Utility
David	40%	1	0.1	0.9
Steve	20%	0.9	0.2	0.7
John	20%	0.7	0.1	0.6

Table 9. Round 2, The solution proposed by Steve showing the percentage of water for each stakeholders and the corresponding benefit, damage and the calculated utility which is the damage subtracted from the benefit

Stakeholder	Water percentage	Benefit	Damage	Utility
David	40%	0.9	0.1	0.8
Steve	25%	1	0.1	0.9
John	30%	1	0.2	0.8

Table 10. Round 2, The solution proposed by John showing the percentage of water for each stakeholders and the corresponding benefit, damage and the calculated utility which is the damage subtracted from the benefit

Stakeholder	Water percentage	Benefit	Damage	Utility
David	40%	0.9	0.1	0.8
Steve	25%	1	0.2	0.8
John	35%	1	0.1	0.9

Table 11. Round 2, Rating values from each stakeholders to others about the solutions proposed. This value contributes to updating the trust value for each participant

Stakeholder	Trust value	Stars
David	Steve	3
David	John	5
Steve	David	1
Steve	John	5
John	David	1
John	Steve	3

So, it is going to be 0.7, 0.9 and 1 for David, Steve and John. After updating the trust value, the fairness index is quantified using the utilities computed by each stakeholder. The fairness index is calculated according to Jain's fairness index. Table 12 shows the computed fairness index for each proposed solution.

Table 12. Round 2, The solution proposed by John showing the percentage of water for each stakeholders and the corresponding benefit, damage and the calculated utility which is the damage subtracted from the benefit

Stakeholder	Fairness	Trusted Fairness
David	0.971	0.679
Steve	0.996	0.996
John	0.996	0.996

Finally, the stakeholder decides on which solution to take by considering the maximum trusted-fairness index. If they do not agree, then they repeat the above process until they decide on a solution.

7 Conclusion

In this work, we presented trust-based multi-stakeholder decision-making for water allocation to help the participants to be able to select the solution comes from the best model. Several criteria involved when deciding on the solution to choose such as Trust, Damage, and Benefit. The preferred scenario is when having a high trust, low damages, high benefits. The worst scenario is when having a low trust, high damage, and low benefit. However, in reality, where different stakeholders are involved, it is challenging to reach a solution that creates balance for their needs of the resources. Therefore, in the decision-making process, Jain's fairness index has been considered as an indicator of reaching the balance or the equality for the stakeholders needs. Other challenges occur is that when the stakeholder is not reliable in term of knowledge and expertise, and then propose a solution by claiming it is fair for everyone. For this reason, we considered the trust among stakeholders to avoid such cases. Having Trusted Fairness is useful for ensuring the stakeholder reliability, reducing the stakeholder tendency to request the full amount of resources and increasing the stakeholder's reputation. For the future direction, we will apply our proposed decision-making model in energy allocation.

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