Promoting Collaboration among Stakeholders in Citarum River Basin Problem

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ABSTRACT

This research aims to develop an agent-based simulation model of the dynamic of negotiation based on interaction among autonomous agents, who have different interests and act based on their emotion. Agents in this model are equipped with emotion and ability to learn, and negotiate each other based on drama theory framework. To illustrate the simulation model, an environmental conflict case in Citarum river basin is discussed in this paper. Qualitative study is used to gather information regarding the agent's historical options, positions and preferences. Based on the qualitative study result, the historical dynamics of common reference frame in the real world is obtained. The simulation model is then tested and validated by comparing with historical dynamics of the real conflict in Citarum river basin. Using this simulation, it is possible to describe possible outcomes of the conflict evolution and suggest policy in order to reduce dilemmas and encourage collaboration among agents in the real world.

Keywords: *agent based simulation, drama theory, dilemma, collaboration*

1. Introduction

A conflict, from mere difference of opinion to deadly confrontations, is unavoidable in daily life. Negotiation as an effort to resolve conflict is a very common process in everyday life. This is why negotiation process is studied in many scientific fields such as economy, political science, psychology, organizational behavior, decision sciences, operations research and mathematics [1].

One of conflicts in real worldis a conflict occurred in the Citarum River Basin. Citarum River is the longest river in West Java province. Many people depend on the Citarum River, making it one of the most strategic river in Indonesia. Unfortunately, the condition Citarum River now has changed completely. Since the industrialization in the 80s the Citarum River turned into industrial landfills. At present, there are around 500 textile factories that dispose their waste into Citarum River, many of which are conducted without proper waste treatment. Citarum river condition is worsened by the population explosion in the upstream area. Increasing population has also increased the number of illegal logging and disposal of household waste. As a result, flood always occurs during the rainy season due to sedimentation in downstream areas of rivers and increasing number of barren land. Citarum River Basin problem involves many stakeholders. Based on the literature study and focus group discussion; there are at least 33 stakeholders in Citarum River Basin Conflict. These stakeholders have conflicting interest and then, efforts to restore the condition of Citarum River become more and more difficult.

Negotiation in the real world such as the one in Citarum River Basin conflict posses several characteristics *i.e.*: 1) *Decentralized* [1], *i.e.*, parties in a negotiation have different frames and strategy in seeking resolution of conflict; 2) Involving communication among parties [1]; 3) Decisions of negotiators are interlinked through communication processes that involve many different levels [2]; 4) Involving incomplete information [1], for example, a party cannot know for certain utilities from the other parties; 5) Involving repeated interaction with no well-structured sequences [1]; 6) Emotion is an important device in structuring goals, values and preferences [3] and affects communication [2].

Negotiation process reflects the characteristics of a complex system since: 1) the elements involved in a negotiation process are heterogeneous and autonomous agents (parties); 2) agents involved a negotiation process are bounded rational, so that they may have bias in information and have a misperception toward the other agents; 3) communication process in a negotiation involves transmission of knowledge that will influence the behavior of its recipient; 4) negotiation is an iterative process. Such process involves feed-back loops that allows an agent to learn and revise his/her strategy. Accordingly, the system (condition during the negotiation process in this case) evolves over time [4]; 5) in general, interactions in a negotiation process are non-linear in the sense of, for an action there

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are many possible outcomes that could be produced and, for an outcome there are many possible actions that may cause it.

The objective of this study is to construct an agent-based simulation of the dynamics of negotiation based on drama theory framework. Agents in the simulation model are equipped with emotions and ability to learn. The agent-based simulation is chosen because it can minimize the number of simplifications used by its ability to fully represents individuals and model bounded rational behavior while, drama theory is chosen because, it proposes an episodic model whereby situations unfold. Using the constructed model, this study will propose strategy that can promote collaboration among stake holders in Citarum River Basin Conflict.

2. Proposed Mechanism

2.1. Model of Agent's Options, Position and Threat

In drama theory, there are a number of agents who have options, positions, preferences and threats. Interaction among agents occurred under the common reference frame that is, the joint perception regarding the conflict that occurs. In this simulation, an agent is represented as a column in a common reference frame. Each agent *i*, has a number of options (O_{ki}) that are represented as rows in common reference frame. At each iteration *t*, agent *i* has position to *accept* or to *reject* each its own option. Agent *i*'s position toward its own options will generate payoff (Vo_{ki}^t) for the agent *i*. Agent *i*'s payoff has two dimensions namely *accept dimension* and *reject dimension*. If agent *i*'s position is to accept option O_{ik}, then agent *i*'s payoff in *accept dimension* is assigned as *x* (a real number between 51 to 100) and, agent *i*'s payoff in the *reject dimension* is assigned as (100 – *x*). The opposite rule applies if agent *i* position is to reject option O_{ik}.

Each agent *j* ($j \neq i$), has position *to accept*, *reject* or *indifferent* toward option O_{ik} of agent *i*. Agent *j*'s position toward agent *i*'s options will generate payoff (Vpo_{kij}^t) for agent *j*. Agent *j*'s payoff consists of two dimensions, namely *accept dimension* and *reject dimension*. If agent *j*'s position is to accept option O_{ik}, then agent *j*'s payoff in *accept dimension* is assigned as *x* (a real number between 51 and 100) and, agent *j*'s payoff in *reject dimension* is assigned as (100 – *x*). The opposite rule applies if agent *j* position is to reject option O_{ik} of agent *i*. If agent *j*'s position is *indifferent* toward option O_{ik} of agent *i* then agent *j*'s payoff in both dimensions are assigned as 50.

The total real payoff obtained by each agent by adopting its own positions in each iteration *t* is calculated as follows:

$$Vp_i^t(p_i^t) = Vo_{ki}^t + \sum_m Vpo_{kij}^t \qquad (1)$$

m = number option and ($i \neq j$)
p_i^t = positions of agent *i* in iteration *t*

While, the total payoff obtained by agent *i* by adopting agent *j*'s positions in each iteration *t* is calculated as follows:

$$Vpp_i^t(p_j^t) = Vo_{ki}^t + \sum_m Vpo_{kij}^t \qquad (2)$$

m = number option and ($i \neq j$)
p_j^t = positions of agent *j* in iteration *t*

Both payoffs are stored in *real payoff matrix*. The columns of this matrix represents agent *i* and the rows of this matrix represents agent *j*. The elements on the diagonal of the *real payoff matrix* represent the payoff that will be obtained by each agent by adopting its own position.

For all options, a set of threats is defined. The total payoff obtained by agent *i* by adopting threatened future in each iteration *t* is calculated as follows:

$$Vpt_i^t(T) = Vo_{ki}^t + \sum_m Vpo_{kij}^t \qquad (3)$$

m = number option and ($i \neq j$)
T = threat

Each agent *i* has an estimation regarding the payoff that will be obtained by other agents for each of their position. Agent *i*'s estimation toward agent *j*'s payoff is also consists of two dimensions, *i.e. accept dimension* and *reject dimension*. If agent *j*'s accepting option O_{ik}, then agent *i* estimates that agent *j* will obtain payoff equal to *x* (*x* is a random number from 51 to 100) in *accept dimension* and *100- x* in *reject dimension*. The opposite rule applies if agent *j* is rejecting option O_{ik}. If agent *j* is indifferent toward option O_{ik} then, agent *i* estimates that agent *j*'s payoff in both dimensions are equal to 50. All agents store their estimation regarding other agent's payoffs in *estimated accepting payoff* matrix and *estimated rejecting payoff* matrix. The columns of agent *i*'s *estimated payoff matrices* represent agent *j* and the rows represent option O_{ik}.

2.2. Modeling Agent's Dilemmas

In each iteration, if agent *i* and agent *j* have incompatible position (*e.g.* agent *i* accept option O_{ik} while agent *j* reject the option) among them, then confrontation dilemmas will emerge. Agent *i*'s dilemmas toward agent *j* are determined by the payoff that will be obtained by agent *i*. There are two kinds of dilemmas that are considered in this research, *i.e.* rejection dilemma and persuasion dilemma [5]. Those dilemmas are defined as follows:

- If agent *i*'s payoff by adopting agent *j*'s position is greater than or equal to agent *i*'s payoff to adopt its own threat then, agent *i* has rejection dilemma toward agent *j*.
- If agent *i*'s payoff by adopting agent *j*'s position is less than or equal to agent *i*'s payoff to adopt its own threat then, agent *j* has persuasion dilemma toward agent *i*.

If there are no incompatible positions among agents, the collaboration dilemmas still may occur. The collaboration dilemma considered in this research is trust dilemma. Agent *i* who has compatible position with agent *j*, will have trust dilemma toward agent *j*, if agent *i*'s estimation regarding agent *j*'s payoff is not in accordance with agent *j*'s position. For example, agent *i* will have trust dilemma toward agent *j* if both agent *i* and *j* accept option O_{ik} but agent *i* estimates that agent *j* will have greater payoff by rejecting option O_{ik}.

2.3. Negotiation Protocols

In this negotiation protocol, each agent is equipped with emotion that is modeled using PAD temperament model [6]. In this model, emotional state is constructed by three independent dimensions *i.e.* Pleasure , Arousal and Dominance. The formulation of agent's emotional state is as follows [7].

$$Se_{ij}(r_p, r_a, r_d) = r_p.(1 + r_a) - r_d \tag{4}$$

During the simulation, an agent conducts negotiation with a partner for options on which they have incompatible positions between them (*e.g.* agent *i* accept the option while agent *j* reject the option). The negotiation protocol in this research is constructed based on rational negotiation framework in which, agent *i* will offer certain amount of its payoff (st_i) to agent *j* in order to influence agent *j* to change his/her position closer to agent *i*'s position. The potency of agent *i*'s offer to shift agent *j*'s position (Ov_{ij}) is affected by agent *i*'s emotional state toward agent *j* (Se_{ij}), and agent *j*'s perception toward agent *i*'s offer (Ov_{ji}) is affected by agent *j*'s emotion toward agent *i* (Se_{ji}).

$$Ov_{ij} = Se_{ij} \times st_i + st_i \tag{5}$$

$$Ov_{ji} = Se_{ji} \times Ov_{ij} + Ov_{ij} \tag{6}$$

Suppose agent *i*'s position is to accept option *k* and agent *j*'s position is to reject option O_{ik}, then agent *i*'s payoff in *accept dimension* will then subtracted by Ov_{ij} and agent *i*'s payoff in *reject dimension* is added by Ov_{ij} while, agent *i*'s estimation toward agent *j*'s payoff in *reject dimension* is also subtracted by Ov_{ij} and agent *i*'s estimation toward agent *j*'s payoff in *accept dimension* is added by Ov_{ij}. On the other hand, agent *j*'s payoff in *accept dimension* is added by Ov_{ji} and agent *j*'s payoff in *reject dimension* is subtracted by Ov_{ji} while, agent *j*'s estimation toward agent *i*'s payoff in *reject dimension* is added by Ov_{ij} and agent *j*'s estimation toward agent *i*'s payoff in *accept dimension* is substracted by Ov_{ij}.. Similar rules apply for the opposite condition.

For each iteration, an offer from agent *i* is perceived by agent *j*, and agent *i* will compare the response of agent *j* with agent *j*'s response in the previous iteration. Then, agent *i*'s emotion state toward agent *j* will change according to the concept of Flow Model of Emotion [8] which then mapped into PAD dimensions.

Table 1. Change in Agent *i*'s emotional states

Agent *i* offer (compare to previous iteration)	Agent *j* perception (compare to previous iteration)	Change in agent *i* emotion state toward agent *j*		
		r_p	r_a	r_d
Higher	higher	+	+	+
Higher	lower	-	+	+
Lower	higher	+	+	-
Lower	lower	-	-	-

Through the negotiation process agents will learn to identify the emotional state that can produce the biggest shift in position of other agents (best emotional state). Learning mechanism which is built in this study is based upon the assumption that each agent will revise his/her emotional state according to his/her experiences in the previous iterations. Each time agent *i* gives an offer to agent *j*, agent *i* will record emotional state that he/she use and the shift resulted in agent *j*'s position. If in the current iteration the shift in agent *j*'s position is higher or equal to the shift in agent *j*'s position in the previous iteration then, agent *i* will revise his/her best emotional state according to his/her emotional state in the current iteration [9].

3. Case Study: Citarum River Basin Conflict

The simulation model in this study is constructed by using NetLogo version 4.1.2. In this study, the common reference frame of the Citarum River Basin conflict is used as the simulation input. This Common reference frame was identified through observation and focus group discussion with the stake holders in Citarum River Basin conflict. Through this qualitative study five agents was identified *i.e.* Government (G), Public Enterprise (PE), Green (GR), Community Alliance (CA), Enterprise (E). Agent's options, positions, and threat are described in Table 2.

Table 2. Common Reference Frame in Citarum River Basin Conflict

Options	Threat	CA	E	G	GR	PE
Community Alliance						
Stop seasonal agriculture	N	Y	N	Y	Y	Y
Anarchy demonstration	Y	Y	N	N	N	N
Conducting government advices	N	N	N	Y	Y	Y
Enterprise						
Stop polluting citarum river	N	Y	N	Y	Y	Y
Stop damaging drainage	N	Y	Y	Y	Y	Y
Do CSR	N	Y	Y	Y	Y	Y
Government						
Give sanction to offender	Y	Y	N	Y	Y	Y
Coordinating among agencies	N	Y	Y/N	Y	Y	Y
Stop permitting destructive residential and industry	Y	Y	N	N	Y	Y
Implement recovery program for Citarum	N	Y	Y	y	y	y
Give more authority to NGOs and Public Enterprise	N	Y/N	Y/N	N	Y	Y
Green						
Help government	N	Y	Y/N	Y	Y	Y
Protest the government policies	Y	Y	Y	N	Y	Y/N
Public Enterprise						
Pro active for agencies sustainability	N	Y	Y	Y	Y	Y

During the simulation process, three scenarios are tested. In the first scenario, agents are negotiating by using a negative emotion toward other agents. In this scenario, the value of pleasure, arousal and dominance of each agent towards the other agents are set randomly from 0 to -1. In the second scenario, agents are negotiating by using a neutral emotion toward other agents. In this scenario, the value of pleasure, arousal and dominance of each agent are set as zero. In the third scenario, agents are negotiating by using a positive emotion toward other agents. In this scenario, the value of pleasure, arousal and dominance of each agent towards the other agents are set randomly from 0 to 1. The random assignment of the emotional dimensions is conducted because it is not possible to conduct empirical measurement because of many stake holders in the real world.

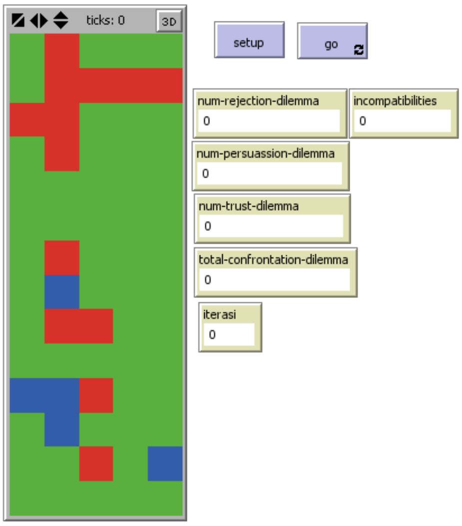

Figure 1. Simulation Interface

Each scenario is run thirty times. In every run, the number of iterations needed to eliminate confrontation dilemmas and the number collaboration dilemmas that occur when the position of all agents have been compatible are observed. Assuming each run as a sample then, the simulation results can be tabulated and tested using ANOVA to observe the differences among scenarios. The comparison among scenarios is shown in Table 3.

Table 3. Comparison among scenarios

Multiple Comparisons							
Tukey HSD							
						Interval	
Dependent Variable	(I) Scenario	(J) Scenario	Mean Difference (I-J)	Std. Error	Sig.	Lower Bound	Upper Bound
Trust	1	2	8.30000*	1.22259	.000	5.3579	11.2421
		3	10.70000*	1.22259	.000	7.7579	13.6421
	2	1	-8.30000*	1.22259	.000	-11.2421	-5.3579
		3	2.40000	1.22259	.131	-.5421	5.3421
	3	1	-10.70000*	1.22259	.000	-13.6421	-7.7579
		2	-2.40000	1.22259	.131	-5.3421	.5421
Iteration	1	2	498.00000*	58.23422	.000	357.8641	638.1359
		3	530.10000*	58.23422	.000	389.9641	670.2359
	2	1	498.00000*	58.23422	.000	-638.1359	-357.8641
		3	32.10000	58.23422	.846	-108.0359	172.2359
	3	1	530.10000*	58.23422	.000	-670.2359	-389.9641
		2	-32.10000	58.23422	.846	-172.2359	108.0359

The comparison results shows that if agents use negative emotions to other agents during the negotiation process then, in average the time required to eliminate the confrontation dilemmas will be longer than if they use neutral or positive emotions. In addition, the numbers of collaboration dilemmas that arise when agents use negative emotions are significantly higher than if they use neutral or positive emotions.

4. Conclusions

Through this study, an agent-based simulation of the dynamics of negotiation using drama theory frame-work have been constructed. The simulation model has involved agent's emotions and learning ability in the negotiation protocol. This model is able to show the evolution of common references, and show the effect of agent's emotional states toward the number of dilemmas resulted in the given common reference frame, the time required to eliminate confrontation dilemmas and the collaboration dilemmas that potentially arise after all agents reach compatible positions.

The proposed model is applied to analyze the conflict in Citarum River Basin. Based on the simulation results it can be concluded that if agents use negative emotions to other agents during the negotiation process then, the time required to eliminate the confrontation dilemmas will be longer than if they use neutral or positive emotions. In addition the simulation results also show that the numbers of collaboration dilemmas arise when agents use negative emotions are significantly higher than if they use neutral or positive emotions. In the real world, positive emotions can be implemented in several forms, for examples, willingness to compromise, giving empathy to others and convincing others etc. Agents who have positive emotion will not threat partners, and impose the will or the anarchist protest .

In the future, the model in this study needs to be improved by integrating other dilemmas such as threat dilemma and positioning dilemma. The feasibility and accuracy of this simulation to represents the evolution real world conflict is important to be investigated.

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