Analyzing Effects of Various Trust in Product Recalls Using a Social Simulation with a Co-Evolution Model

Tetsuroh Watanabe
The University of Tokyo
Tokyo, Japan
morningyrp@gmail.com

Taro Kanno
The University of Tokyo
Tokyo, Japan
kanno@sys.t.u-tokyo.ac.jp

Kazuo Furuta
The University of Tokyo
Tokyo, Japan
furuta@rerc.t.u-tokyo.ac.jp

ABSTRACT

To improve product recall systems, we studied social simulation using a multi-agent system with a co-evolution model. This research is important because empirical approaches are no longer adequate for complex and diverse modern societies. Results of a simulation experiment have revealed the possibility that improving consumer trust in product recall actions is useful for producers and makes it possible to sell expensive products. We believe this work can contribute to support of government staff for improving product recall systems and to support of executive officers of product companies deliberating about recall decision strategies.

CCS CONCEPTS

• **Computing methodologies → Genetic programming**; **Modeling and simulation**; **Multi-agent systems**; • **Applied computing** → *Economics*;

KEYWORDS

Genetic programming, multi-agent simulation, artificial society, multi-objective optimization, decision-making

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1 INTRODUCTION

In recent years, accidents and product recalls related to product defects have come to pose difficulties for corporations, threatening numerous industries worldwide. Consideration of decision-making by producers and their consumers related to product recalls and improving product recall systems is important. Some product recall studies have been pursued using empirical approaches [1, 3]. However, empirical approaches are no longer adequate for complex and diverse modern society because such approaches have insufficient predictive power.

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Watanabe *et al.* conducted social simulation experiments related to product recall systems using a multi-agent system [4]. However, the major shortcoming of that study was that consumer trust in product recalls were completely fixed for simplicity. Daniel *et al.* reports that communication skill related to a product recall of a producer affects consumers' trust and feelings [3].

To address these difficulties, this study was conducted to introduce multiple values of trust in product recalls into a simulation model, and to analyze effects of different degrees of trust. For this study, we construct two groups: producer agents with skill at conducting product recalls and producer agents with poor skill. We analyze the distribution of agents and product sales. Then we obtain suggestions for improving real-world product recall systems.

2 SIMULATION MODEL

2.1 Layered Co-Evolution Model

Genetic programming (GP) and a co-evolution model are applied as the simulation model: a learning model for producers and consumers. Here, *Layered Co-Evolution Model* is a unique simulation model adopted for this work.

The artificial society in the simulation environment has agents of two types: *producer* and *consumer* agents. Each consumer agent belongs to a *user group* of a certain producer agent. Consumer agents can *migrate* to another user group. These agents of two types co-evolve. Fitness of producer agents is their *asset.* Consumer agents optimize their *satisfaction* and *payment* using *SPEA2* [5].

Each consumer agent has *Trust* of the producer agent of a product the consumer uses. Each producer agent has *Total Trust*: the sum of users' Trust. Higher Total Trust indicates a higher probability of being chosen as a migration destination.

2.2 Simulation Flow

The simulation flow of this study is presented in Figure 1. The one-point subtree crossover and the one-point subtree mutation are used for GP reproduction in the Agent Optimization Flow.

We abstract factors related to product recall discussion according to existing studies [1, 3]. Then we add the factors to the Social Simulation Flow. Producer agent decisions can raise production cost ($\propto$ selling price) and conduct a product recall leading to accident rate reduction.

2.3 Logic Value Typed GP

All agents respectively decide how they act at the yellow box in Figure 1. For agents' decision-making, we use *Logic Value Typed GP*, an extended method from Booleanized GP [2]. Logic Value Typed GP uses *three-valued logic*, which uses "the third logic value", called *Undefined.*

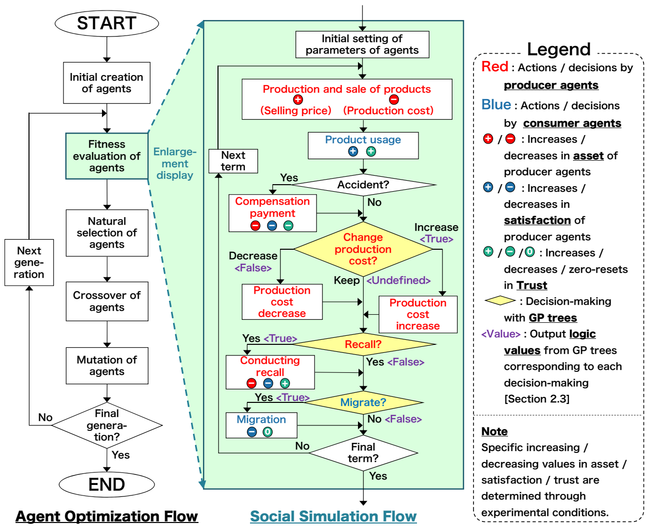


Figure 1: Simulation flow chart.

Agent type	Decision-making type	Input: Logic value type	Output: True	Output: Undefined	Output: False
Producer	Conduct Recall?	Boolean	Yes	———	No
	Change cost?	Three-valued logic	Increase	Keep	Decrease
Consumer	Migrate?	Boolean	Yes	———	No

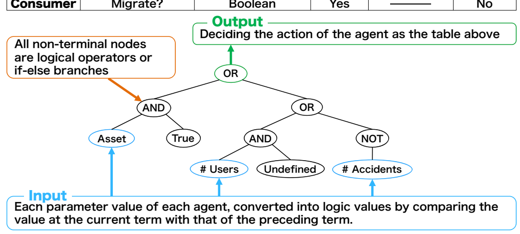


Figure 2: Overview and an example of Logic Value Typed GP.

An agent has its own GP tree. Each parameter value of each agent is converted into logic values by comparing the value at the current term with that of the prior term. Figure 2 depicts an overview and an example of Logic Value Typed GP tree, with corresponding decisions of agents.

3 MULTIPLE POPULATIONS OF PRODUCER AGENTS

As described in Section 1, we introduce two populations of producer agents. Different values of trust in a product recall action (plus, minus) are set to producer agents in each population, as shown in Figure 3.

In connection with the real world, producer agents with plus recall trust have good product recall communication skills, *i.e.*, the producer agents can elicit high trust in their product recall actions from users[3].

4 RESULTS AND DISCUSSION

Figure 4 presents results of our simulation experiment: distributions of producer agents at the final (120th) term in the final (300th) generation. Star-shaped markers denote producer agents ranked in the top 5% product sales.

Figure 4a demonstrates that the Total Trust of producer agents shown as blue dots (Trust in a recall: +10) tends to be greater than those shown as red dots (Trust in a recall: −10).

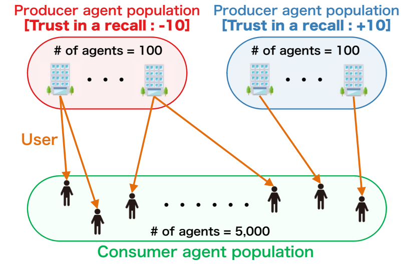
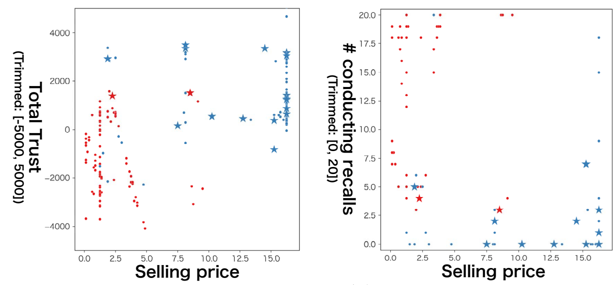


Figure 3: Multiple populations of producer agents.



(a) Selling price / Total Trust. (b) Selling price / # recalls.

Legend	Trust in a Recall : -10	Trust in a Recall : +10
Ranked top 5% product sales	★ (red)	★ (blue)
Not ranked top 5% product sales	● (red)	● (blue)

Figure 4: Result – Distribution of producer agents.

It is noteworthy for Figure 4 that blue star markers are observed more than red ones in areas of higher prices than in those of lower prices, meaning that producer agents conducting product recalls with high trust can sell many products even at high prices. By contrast producer agents conducting recalls with poor communication skills cannot sell many products even at lower prices and even with frequent recalls (Fig. 4b). These phenomena suggest the importance of improving consumer trust (or feelings) in product recall actions.

5 CONCLUSION

In summary, we constructed a social simulation model to analyze effects of differences of trust in product recalls. Results revealed the possibility that improving consumer trust in product recall actions is useful for producers. Moreover, it can support sales of expensive products. It is noteworthy that this inference can be made using the quantitative and predictive approach explained herein. This work can contribute to support of government staff and improve product recall systems, and to support of product company executives deliberating recall decision strategies.

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