

# Model of Trust Dissemination of Products Based on Fuzzy Aggregation Norms

Oleksandr Sokolov

Faculty of Physics, Astronomy and Informatics,  
 Nicolaus Copernicus University in Torun  
 Grudziadzka 5, 87-100 Torun, Poland  
 Email: osokolov@fizyka.umk.pl  
 ORCID 0000-0002-6531-2203

Aleksandra Mrela

Institute of Informatics  
 Kazimierz Wielki University in Bydgoszcz,  
 Chodkiewicza 30, 85-064 Bydgoszcz, Poland  
 Email: a.mrela@ukw.edu.pl  
 ORCID 0000-0002-2059-864X

Maryla Bieniek-Majka

Institute of Law and Economics  
 Kazimierz Wielki University in Bydgoszcz  
 Chodkiewicza 30, 85-064 Bydgoszcz, Poland  
 Email: maryla@ukw.edu.pl  
 ORCID 0000-0003-1448-7406

Veslava Osinska

Department of Information Space Research  
 Institute of Information & Communication Research  
 Nicolaus Copernicus University in Torun  
 ul. Wladyslawa Bojarskiego 1, Torun, Poland  
 Email: wiewo@umk.edu.pl  
 ORCID 0000-0002-1306-7832

Wlodzislaw Duch

Faculty of Physics, Astronomy and Informatics,  
 Nicolaus Copernicus University in Torun  
 Grudziadzka 5, 87-100 Torun, Poland  
 Email: duch@fizyka.umk.pl  
 ORCID 0000-0001-7882-4729

**Abstract**—Companies and even institutions have recently tried to form a reasonable opinion about their products. One way companies can achieve this is to prepare and distribute advertisements. Some advertising media, such as TV commercials, are costly and tiresome, so understanding and modeling some aspects of disseminating product information might be helpful. The article presents a multi-agent model of spreading trust in the product among agents based on fuzzy aggregation norms. When people with a similar opinion about a product discuss it with others or listen to a commercial, their trust increases, so the optimistic fuzzy aggregation norm is applied. When people with different opinions meet, their faith decreases, so the pessimistic norm is applied. In addition, the paper presents a theoretical example of this model application, namely, showing the results of a multi-agent model of spreading confidence in the product and presenting the results of the NetLogo simulation.

**Index Terms**—trust dissemination, multi-agent model, fuzzy aggregation norms, NetLogo application

## I. INTRODUCTION

THE advertisement is present everywhere and slowly has been filling up people's everyday reality, and it is one of the systematic business processes where companies use technology. The methods used for helping people solve different business problems and based on information systems that start as practical business applications should also be analyzed at the conceptual level at the beginning by considering case studies, for example [1], [2].

This paper aims to present a theoretic model of spreading information about a product using fuzzy aggregation norms applicable in the area of product advertisement. The article also deals with searching for a method to observe the dissemination of knowledge about products applying the concept of an agent or an intelligent agent to analyze, model, and visualize the considered process using the NetLogo application. Multiagents' idea is used to analyze customer service, sales, and production scheduling [3], [4].

## II. FUZZY LOGIC

When people describe the product, they may use words on the two extreme levels of the scale of product appreciation, like perfect or worst, or some intermediate terms like good, excellent, or wrong. Hence, fuzzy logic is much better to apply than classical logic [5].

L. Zadeh [6] introduced the concept of fuzzy sets. Let  $X$  be a non-empty space. Then  $A \subseteq X$  is called a fuzzy set if it is a set of pairs  $\{(x, \mu_A(x)), x \in X\}$ , where  $\mu_A : X \rightarrow [0, 1]$  is a membership function. Value  $\mu_A(x)$  describes the level of membership of element  $x$  to set  $A$ .

## III. THE FUNCTION OF TRUST DISSEMINATION

The article deals with the dissemination of products of knowledge or the reputation of scientists. Assume that we are

interested in the advertisement for one product, which will be called later the product.

Let  $\mathcal{A}$  denote the set of agents - people who might have some knowledge about the product and some level of trust about its quality. Let  $T : \mathcal{A} \rightarrow [0, 1]$  be called the trust function. Assume that  $A \in \mathcal{A}$  and let us consider five cases:

- $T(A) = 1$ , then the trust of agent  $A$  is positive and perfect, there is no way to change their minds about the product;
- $T(A) \in (0.5, 1)$ , then the agent's trust in the product is high;
- $T(A) = 0.5$ , then agent  $A$  does not have any knowledge or is perfectly indifferent to the product;
- $T(A) \in (0, 0.5)$ , then the trust is low;
- $T(A) = 0$ , then agent  $A$  does not have any knowledge, or they dislike the product.

Now we will consider the situation when agents meet and discuss the product or get some new information about it from, for example, a TV commercial.

#### IV. OPTIMISTIC FUZZY AGGREGATION NORMS

The essential characteristic of optimistic fuzzy aggregation norms is that the examined property level is not less than before.

Let  $I = [0, 1]$ . Then  $S_o : I \times I \rightarrow I$  is called an optimistic fuzzy aggregation norm if it fulfills the following conditions for each  $x, y \in I$ :

- (O1)  $S_o(0, 0) = 0$
- (O2)  $S_o(x, y) = S_o(y, x)$
- (O3)  $S_o(x, y) \geq \max\{x, y\}$

Let us notice that it can be easily seen that

- (O4)  $S_o(x, 0) \geq x$  for each  $x \in I$
- (O5)  $S_o(1, 1) = 1$

Condition (O1) shows that if an agent's trust in the product is 0 and they do not get any new information about it, their faith stays on zero levels (as before). Condition (O2), called commutativity, says that the order of getting pieces of information about the product does not matter. Thanks to condition (O3), we know that the product trust value is not less than the level after the meeting with another agent or watching the ad.

Additionally, condition (O4) indicates that if the level of trust in the product is positive and if the agent does not get any new pieces of information or advertisement, then the level of confidence is not reduced.

Let us choose as an optimistic aggregation norm the following function  $S_o(x, y) = x + y - xy$  for each  $x, y \in I$ . In this case,  $S_o(x, 0) = x$  for each  $x \in I$ .

Let us consider an example. Assume that two agents  $A_1$  and  $A_2$ , with the level of trust  $t_1 = 0.6$  and  $t_2 = 0.7$  respectively, meet and discuss the quality of the product. To calculate the trust of the agents we apply optimistic fuzzy aggregation norm:  $T(A_1) = S_o(A_1, A_2) = t_1 + t_2 - t_1 \cdot t_2 = 0.6 + 0.7 - 0.6 \cdot 0.7 = 0.88$ . By (O2), we know that  $T(A_2) = S_o(A_2, A_1) = S_o(A_1, A_2) = 0.88$ . Hence, the trust of both agents is equal and higher than before the meeting. Let us notice that the trust in the product of both agents in the product is strengthened.

#### V. PESSIMISTIC FUZZY AGGREGATION NORMS

The essential characteristic of pessimistic fuzzy aggregation norms is that the examined property level is not higher than before.

Let  $I = [0, 1]$ . Then  $S_p : I \times I \rightarrow I$  is called a pessimistic fuzzy aggregation norm if it fulfills the following conditions for each  $x, y \in I$ :

- (P1)  $S_p(1, 1) = 1$
- (P2)  $S_p(x, y) = S_p(y, x)$
- (P3)  $S_p(x, y) \leq \min\{x, y\}$

Let us notice that it can be easily seen that for each  $x \in I$  we have

- (P4)  $S_p(x, 1) \leq x$
- (P5)  $S_p(0, 0) = 0$

Condition (P1) shows that if an agent believes in a product entirely and they get any new information about it, their belief stays on the same one (maximal) level (as before). Condition (P2), called commutativity, says that the order of getting pieces of information about the product does not matter. Condition (P3) shows that if the level of belief in a given product is not higher than the level of confidence in this product before and the new piece of faith the agent gets while speaking to other agents or the source of advertisement (TV, radio). Additionally, condition (P4) indicates that if the level of belief in a product is positive and if the agent gets the new perfect piece of information or advertisement, then the value of confidence is not increased.

Let us choose as a pessimistic aggregation norm the following function  $S_p(x, y) = xy$  for each  $x, y \in I$ . Then we can easily see that condition (P4) we can write as follows  $S_p(x, 1) = x$ .

Let us consider an example. Assume that  $A_1$  and  $A_2$  are agents with the level of trust  $t_1 = 0.2$  and  $t_2 = 0.4$ , respectively. After meeting and discussing the quality of the product, we can calculate the trust of the agents applying the pessimistic fuzzy aggregation norm:  $T(A_1) = S_p(A_1, A_2) = t_1 \cdot t_2 = 0.2 \cdot 0.4 = 0.08$ . By (P2),  $T(A_1) = T(A_2)$ . Of course, the trust in the product is lower for both agents.

Assume that agent  $A$ , with the trust  $t$ , does not meet another agent to discuss the product; their faith in the product after some time will be smaller and equal to  $T(A) = S_p(t, t)$ .

Let us consider another example. Let agent  $A$ , with the trust  $t = 0.3$ , does not discuss the qualities of the product and does not listen to the advertisement, then after some time:  $T(A) = S_p(t, t) = 0.3 \cdot 0.3 = 0.09$ . As we can quickly notice, their trust in the product lowered. When people do not listen to any information about the product or do not discuss it with other people, their confidence in the merchandise decreases. There is one exception, perfectly convinced people. They do not need any advertisement or talking to other people about the product, and their trust is still on level 1:  $T(A) = 1 \cdot 1 = 1$ .

#### VI. MULTI-AGENT MODEL OF THE TRUST-IN-THE PRODUCT DISSEMINATION

Let  $A$  be an agent with the level of trust in the product equals  $t \in [0, 1]$  in some period. To design the model of the

trust-in-the-product dissemination, let us consider three cases.

- If for a given period, the agent does not meet other agents to discuss the product and does not watch any advertisement; then we can assume that their trust in the product suppresses with the forgetting coefficient  $F$  belonging to interval  $[0, 1]$ .
- If in a given period, the agent is exposed to advertising of the product or is in the shop selling the product, we can assume that their trust in the product increases with the strengthening coefficient  $S \in [0, 1]$ , which value depends on the level of aggressiveness of this ad.
- If agent  $A$  meets other agents  $A_1, A_2, \dots, A_n$  with levels of trust in the product equal to  $t_1, t_2, \dots, t_n$ , respectively, then  $A$ 's confidence in the product also increases. Hence the strengthening coefficient  $M$  can be calculated as a maximum of all agents' trust in this merchandise,  $M = \max\{t, t_1, t_2, \dots, t_n\}$ .

Hence, for the next period of time, agent  $A$  trust in the product is calculated in the following way:

$$T(A) = \begin{cases} S_p(t, F) & \text{if } A \text{ has no contact with the advert} \\ S_o(t, S) & \text{if } A \text{ is exposed to the advert} \\ S_o(t, M) & \text{if } A \text{ has meetings with other agents} \end{cases}$$

Let us consider the example. Assume that agent  $A$  with the level of the trust in the product equals  $t = 0.5$  in January. This agent goes for a winter holiday and does not discuss the product's properties and is not exposed to the advertisement of it in February, so the forgetting coefficient is equal to  $F = 0.9$ . In March, this agent takes part in the meeting with two agents  $A_1$  and  $A_2$  with the levels of trust in the product equal to  $t_1 = 0.3$  and  $t_2 = 0.7$  in March. Finally, this agent watches a fascinating film on TV with the product's advert in April, so the strengthening coefficient is equal to  $S = 0.8$ .

Let  $t_{month} = T(A, \text{month})$  denotes this agent's level of trust in the product in the considered month. Hence,  $t_{Jan} = T(A, \text{January}) = 0.5$ . Next,  $t_{Feb} = T(A, \text{February}) = S_p(t_{Jan}, F) = S_p(0.5, 0.9) = 0.5 \cdot 0.9 = 0.45$ . Afterwards,  $M = \max\{0.45, 0.3, 0.7\} = 0.7$  and  $t_{March} = T(A, \text{March}) = S_o(t_{Feb}, M) = S_o(0.45, 0.7) = 0.45 + 0.7 - 0.45 \cdot 0.7 = 0.84$ . Finally,  $t_{Apr} = T(A, \text{April}) = S_o(t_{March}, S) = S_o(0.84, 0.8) = 0.84 + 0.8 - 0.84 \cdot 0.8 = 0.97$ . Thus, the presented multi-agent model can simulate the levels of agents' trust in the product and the influence of other agents and the product advertising on the agents' trust level.

## VII. SIMULATION OF THE MODEL OF THE TRUST DISSEMINATION

A multi-agent simulation of the trust dissemination of the product was developed in NetLogo's programmable modeling environment, in which applications coded in NetLogo are very convenient to observe agents (turtles) meeting and changing their opinions about the product.

The simulation started with the group of people represented by gray turtles showing no knowledge about the product and advertising media represented by green squares. The simulation follows the Ant Colony Optimization [7] algorithm, which

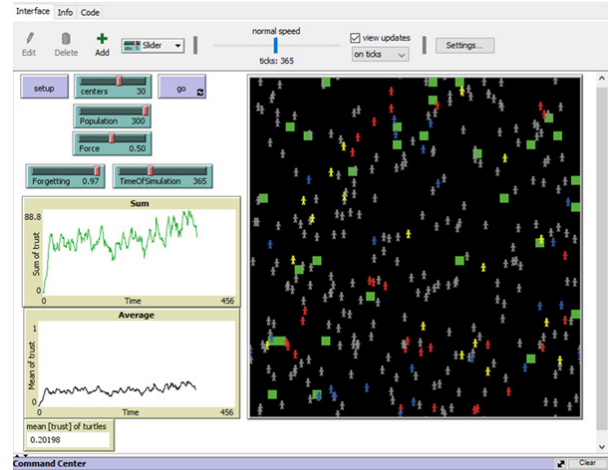


Fig. 1. The screenshot of the middle phase of the application developed for the simulation of the trust in the product

applies probability to solve some computational problems that require looking for paths while traversing plots.

During the simulation, people move, meet other people (during these meetings, they exchange opinions about the product), and meet advertising media (get some information about the product). Initially, the agents' trust in the product is 0, and the media's is 0.9. During the meetings, the product's trust changes according to the fuzzy aggregation norms. Hence, after some time, agents change their colors according to the following rules: they stay gray (the trust is smaller than 0.3), change color to yellow (the trust is between 0.3 and 0.6), - to blue (the trust is between 0.6 and 0.9) or - to red (the trust is greater than 0.9).

## VIII. DISCUSSION

According to K. Kubiak, referring to A. Lubecka, the subject of advertising, has become one of the most frequently discussed issues [8]. Institutions that use advertising to influence the expected behavior use various methods of reaching a specific audience [9]. In advertising design, the most commonly used methods are: evoking intense emotional states, making promises (positive and negative), and using the image of a public figure. According to the theory of stereotypes, ad recipients remember these performances as relatively permanent. Time constraints or the size of the advertising space, combined with the willingness to communicate, impose the need to schematize (stereotype) the presented events, so stereotypes are used because they function on the scale of society [8].

Even the most straightforward messages affect the knowledge, emotions, or behavior of the recipient, sometimes regardless of the will of the message sender. However, there are cases of manipulating the other person. However, honesty towards the customer is not the primary determinant of the product promotion process for some advertisers. Persuasive and argumentative techniques may lead to stereotypes' consolidation in the social consciousness [10].

Advertisements influence emotions and affect product ratings and consumer attitudes. Scientists dealing with this topic pointed to the vital role of activating memories by advertising. The strength of emotional reactions also depends on the purpose of viewing the ad. In the minds of consumers, the goals of observing advertisements may be different; for example, some people want to get information about a product or have the pleasure of viewing the aesthetic images. Thanks to cognitive engagement, product information is processed more accurately, and emotional engagement results in a more positive attitude towards advertising. Therefore, referring to memories will increase involvement in processing information about an advertisement, influencing its evaluation and remembering [5].

In increasing skepticism about the content and declining credibility of messages about products and services, customers' opinions are more important. In recent years, word-of-mouth marketing, also known as gossip or recommendation marketing, is becoming more critical. Its popularity results from people's psychological construction because they need to share their opinions with others [14]. Therefore, the companies found their hope in word-of-mouth marketing, that is, a selfless recommendation of products, brands, or services among their families, friends, or strangers [13].

Word-of-mouth marketing is the oldest, best and cheapest marketing tool. When people tell the truth about a product, the effect of such advertising can be striking, but impersonating an ordinary user praising the product can lead to a loss of trust and turn against the trader [13]. Word of mouth marketing distinguishes into two forms, i.e., face-to-face marketing and online communication [11]. eWOM (electronic word of mouth marketing) has recently attracted much interest from researchers. However, with consumers' increasing dependence on information retrieval and the continued growth of social media, the importance of eWOM should not be overstated [12]. Regardless of the proportion of the phenomenon, the strength of adverse opinions is higher than positive ones. Therefore, the company's task is to strengthen positive thoughts, and weaken negative [14].

Being recognized is very important also for researchers. Scientists build their scientific profiles in only one or a few disciplines or scientific fields, and scientometricians try to find factors to estimate their contribution to a specific discipline or a field. One of the models of computer systems for calculating the contribution to research areas in computer science is presented in [15]. Moreover, bibliometricians try to visualize the scientist's contribution to disciplines based on published articles and journals' profiles by choosing the weights of examined fields empirically [16].

## IX. CONCLUSIONS

We present a model based on fuzzy aggregation norms to describe spreading information about a product that can be applied in product advertisements. We also use several simulations to test the basic assumptions of the model. Selected

actions with predefined emotional states and parameters were simulated in the NetLogo environment.

Summing up, applying optimistic and pessimistic fuzzy norms has the following properties.

- 1) The situation with increasing and decreasing trust of the product among customers can be modeled and analyzed.
- 2) The influence of Advertising Centers can be modeled.
- 3) The role of word-of-mouth marketing and its influence on product trust dissemination can be described.
- 4) Fuzzy aggregation norms can be used to model the product trust dissemination in marketing.

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