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Applying Two-Dimensional Trust Representations to Supporting University Students' Job Hunting — a Case Study with the Non-Cumulative Distrust Levels

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Abstract - In recent years, it has been an important research topic in information security to evaluate the trustworthiness of information. The theory of trust computation deals with trustworthiness as a computational object, enabling us to infer and predict the reliability of information. We have proposed a new method for trust computation, which employs a two-dimensional trust degree that handles trust and distrust simultaneously. We have shown that this method is an extension of Marsh et al.'s well-known one-dimensional trust value method, and our approach is an extension of Jøsang's Subjective Logic. In that sense, our previous results show the technique with a two-dimensional trust value is powerful enough from a theoretical point of view. However, it needs to be clarified how to apply our trust values to real problems. In this paper, we conduct a large-scale case study using two-dimensional trust values. Specifically, we work on a case study of developing a recommender system for employment opportunities that match those based on university students' employment preferences. In our case study, students can answer desired and undesired items as text in an open-ended response format. After analyzing the text, we calculate a trust value, representing an agreement between the student's preferences and the company profile. Since students describe desirable and undesirable items independently and maybe inconsistently, leading to difficulty coping with the inconsistency. Our trust value can deal with this inconsistency, and we determine a trust value without inconsistency by applying the result from the fuzzy logic. This paper also discusses how to assess trust and distrust levels. We show and validate our criteria by comparing them with those in another case study of deciding a trust value to rescue requests posted in a disaster.

Keywords: On-Line Trust, 2D Trust Model, Fuzzy Logic, Job Placement Assistance

1 INTRODUCTION

In recent years, techniques for evaluating trustworthiness in information and senders/receivers are getting crucial. Marsh et al. proposed a method to deal with trustworthiness as a computational object, but their approach has a problem in that it could not handle the independence of trust and distrust degrees. To overcome this problem, we extended Marsh et al.'s trust computation method with the fuzzy logic-based FCR method [1,2]. Our trust computation is two-dimensional, where we can deal with trustworthiness and distrust-worthiness independently. Our previous work [3, 4] has introduced a two-dimensional trust representation, and we have also shown how to analyze transition-related trust properties, such as safety properties. However, we still need to give how to determine the specific trustworthiness and distrust-worthiness when applying our extended trust model to real problems. This paper examines how to determine trust and distrust levels through a case study.

This paper, specifically, deals with a method for recommending companies that match the job preferences of university students based on their job preferences. University students' main interests regarding companies they are employed by are the type of job and workplace location. In this study, we asked university students to answer "what they want" and "what they do not want" regarding these conditions in the form of free descriptions, and based on the results, we calculated a two-dimensional trust value of [3, 4].

Since students tend to describe their preferences and non-preferences independently, the requirements of college students regarding corporate profiles may be inconsistent. We computed the net goodness of fit (called a one-dimensional trust value) of students' preferences to the company profile using the integrated value of the FCR method.

In this study, the assignment of the degree of trust and the degree of distrust was conducted using the same approach as in our previous study, the assignment of a two-dimensional trust value to rescue requests posted during a flood disaster [5]. Specifically, trustworthiness is determined by the degree of compatibility between the text of the company profile and the student's expectations and is a value between 0 and 1. On the other hand, the distrust level is assigned based on whether or not the student's "undesired items" appear in the company profile and has a value of 0 or 1. Although it is possible to determine the distrust level based on "how many unwanted items appear" using the same criterion as the trust level, we did not do so in this study. To validate the criterion of this paper, we discuss how to determine the distrust level properly.

2 PRELIMINARIES: TWO-DIMENSIONAL TRUST REPRESENTATIONS

Marsh and Dibben introduced trust values, which range from -1 to 1, and classified trust notions into *trust*, *distrust*, *untrust*, and *mistrust* [6]. We extended their trust values for two dimensions [3,4] to address inconsistent trust evaluations. This section explains some basics of (mainly two-dimensional) trust computations.

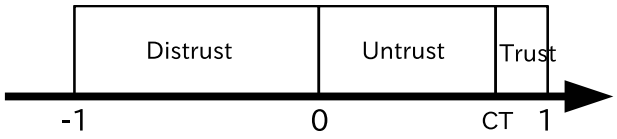

Figure 1: Marsh's trust model

2.1 Conventional Trust Values

A conventional trust value is a real number in $[-1, 1)$. Readers interested in the details of calculating trust values can find them here [6], but in this paper we directly handle the calculated trust values. Marsh and Dibben introduced the following four notions of trust (see also, Fig. 1):

- *Trust*: The notion represents a case where a trust value is positive and exceeds a predefined value called a cooperation threshold (CT). In this case, a trustee should be trusted, and the trust value is regarded as a measure of how much an agent believes the trustee.
- *Distrust*: Here the trust value is negative, and an agent believes that a trustee will actively work against her in a given situation.
- *Untrust*: Although the trust value is positive, it is not high enough to produce cooperation. An agent cannot determine if a trustee is actually trustworthy.
- *Mistrust*: Initial trust has been betrayed. More precicely, mistrust represents a situation either a former trust was destroyed or a former distrust was healed. The mistrust notion is a time-related trust property.

For these properties, see studies by Primiero [7] (on distrust and mistrust) and [8] (on trust and distrust).

2.2 Fuzzy-Logic-Based Two-Dimensional Trust Values

Marsh and Dibben classified trust notions in a one-dimensional setting, i.e., trust and distrust are at both extremities. However, Lewicki et al. [9] suggested that trust and distrust are entirely different dimensions from a psychological viewpoint. Trust is a property closely related to human impressions, and a technique for impression formation based on mathematical psychology should be applied to trust values.

Oda [1, 2] developed a Fuzzy-set Concurrent Rating (FCR) method with fuzzy logic that enables us to measure and analyze human impressions. The FCR method allows two or more dimensions for representing a truth value, and our two-dimensional trust representation is an application of the FCR method for trust and distrust notions.

2.2.1 FCR Method

The FCR method employs the Hyper Logic Space model (HLS) as a logic space for multiple-dimensional multiple-valued logic. Figure 2 shows a two-dimensional space based on $true$ and

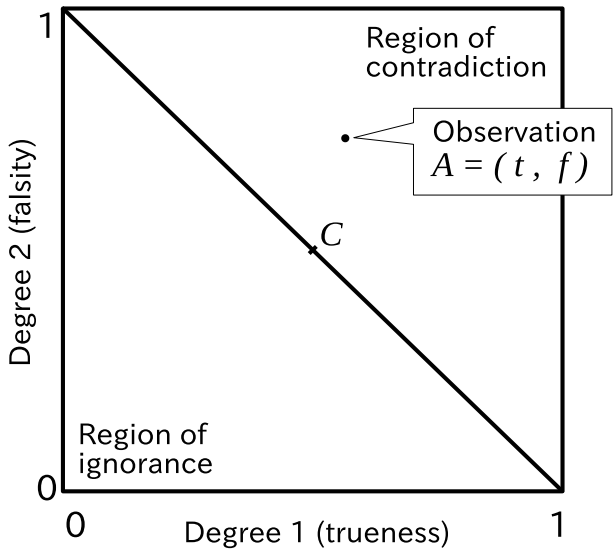

Figure 2: Two-dimensional HLS

$false$. For any $t, f \in [0, 1]$, pair (t, f) is called an observation. t and f are independent; we do not assume such conditions as $t + f = 1$. We call $\{(t, f) \,|\, t, f \in [0, 1] \wedge t + f > 1\}$ the region of contradiction. $\{(t, f) \,|\, t, f \in [0, 1] \wedge t + f < 1\}$ is called the region of ignorance, or the region of irrelevance. Finally, $\{(t, f) \,|\, t, f \in [0, 1] \wedge t + f = 1\}$ is the consistent region.

Given observation (t, f), we need to calculate an actual truth value, which is called an integration value. Integration values can be calculated in several ways, and we employ the reverse-item averaging method, where integration value I_2 is defined with $I_2(t, f) = \dfrac{t + (1 - f)}{2}$. The integration value is the average of the degree of the positive elements and the complementary degree of the negative elements.

Another important value in the FCR method is the degree of contradiction [1,2] or the contradiction-irrelevance degree. In the field of personality psychology, some situations are allowed, including "I like it, but I don't like it" or "I don't care for it at all." The degree of such confusion/irrelevance is formulated with the degree of contradiction. For observation (t, f), degree of contradiction $C(t, f)$ should satisfy $C(t, f) = 1$ for complete confusion, $C(t, f) = -1$ for complete ignorance, and $C(t, f) = 0$ for a consistent situation. $C(t, f) = t + f - 1$ is usually employed where $C(t, f)$ represents the distance between (t, f) and the consistent region.

2.2.2 Two-Dimensional Trust Model

We employ the degrees of trust $Trust$ and distrust $DisTrust$ defined with $Trust = DisTrust = \{\, v \,|\, 0 \leq v \leq 1\}$ and define a two-dimensional trust value as an element of $Trust \times DisTrust$. Observation $(1, 0) \in Trust \times DisTrust$ has a high degree of trust and a low degree of distrust and represents a case where a trustee is completely trusted; this observation corresponds to trust value 1 of [6]. Observation $(0, 1)$ represents a case of complete distrust and corresponds to trust

value -1. Observation $(0.5, 0.5)$, which falls exactly between $(1, 0)$ and $(0, 1)$, corresponds to 0 in conventional trust values.

To define such trust notions as trust, distrust, and untrust in our two-dimensional trust model, we employ the following transformation:

$$\left[\begin{pmatrix}\cos\frac{\pi}{4} & -\sin\frac{\pi}{4}\\ \sin\frac{\pi}{4} & \cos\frac{\pi}{4}\end{pmatrix}\left\{\begin{pmatrix}t\\ d\end{pmatrix}-\begin{pmatrix}1\\ 0\end{pmatrix}\right\}+\begin{pmatrix}\frac{\sqrt{2}}{2}\\ 0\end{pmatrix}\right]\times\frac{1}{\frac{\sqrt{2}}{2}}$$
$$=\begin{pmatrix}t-d\\ t+d-1\end{pmatrix}=\begin{pmatrix}i\\ c\end{pmatrix}.$$

First element $i = t-d$ can be calculated with the reverse-item averaging method. Actually, the value of i is calculated by normalizing $I_2(t, d)$ to be a value in region $[-1, 1]$; note that the range of integration value $I_2(t, d)$ was originally $[0, 1]$.

The value of i was regarded as a conventional trust value given by Marsh and Dibben. From the definition of $i = t - d$, a net trust value is calculated by subtracting the degree of trust from the degree of distrust, which matches our intuition. In Fig. 2, the consistent region is the line between $(1, 0)$ and $(0, 1)$ and corresponds to the set of conventional trust values. Observation (t, d) in the consistent region satisfies $t + d = 1$ and is regarded as an assumption on the trust and distrust degrees. The theory of conventional trust values implicitly introduces this assumption.

Trust notions are defined with the value of i. Let CT be a cooperation threshold. If we have $i = t - d \geq CT$, then it is a case of trust; if i is negative then it is case of distrust; if we have $0 \leq i < CT$, then it is a case of untrust. Note that for the case of distrust, condition $i < 0$ is equivalent to $t < d$; i.e., a trustee is distrusted if the degree of distrust exceeds the degree of trust.

As described above, the i value in our two-dimensional trust model corresponds to Marsh's trust value. Thus, our model is an extension of the one-dimensional model. Moreover, our model is also an extension of Jøsang's Subjective Logic [10]. Subjective Logic, like our model, treats trustworthiness t and distrustworthiness d independently. However, Subjective Logic requires the constraint $t + d \leq 1$. The trust model based on the FCR method has no such constraint. Therefore, our model is an extension of Subjective Logic in that it can handle t and d with $t + d > 1$.

3 CALCULATION OF TWO-DIMENSIONAL TRUST VALUES BASED ON MATCHING OF EMPLOYMENT PREFERENCES AND JOB OFFERS

For applying our two-dimensional trust model to real applications, this section deals with the issue of helping university students find jobs using our two-dimensional trust values. Specifically, we evaluate the degree to which a description in job openings matches the student's preferences as a two-dimensional trust value.

This study focuses on students in the Department of Information Science at Aichi Institute of Technology. Although the students are in the sciences, the percentage of students going to graduate school is about 20%, and most undergraduates wish to find a job. Readers should note that this is a different characteristic from that of students at national universities in Japan. However, private university students account for 70% of the total students in Japan, and we believe that students with this characteristic are not a minority. About 80% of the students commute from the Tokai region of Japan. The general trend is that they are strongly oriented toward the IT industry and hope to live in their hometown (i.e., they wish to work in the Tokai region). The number of job openings is about 15,000, mainly for engineering students. In this section, we focus on the example of one student, but we treated 78 job-seeking students.

```
Preferred items regarding work location:
I prefer to work and live in Nagoya or
Tokyo.  It is also OK to work in my home
town Hamamatsu.

NG items regarding work location:
I'm not particularly eager to go to
outlying areas such as Hokkaido, Okinawa,
and Shikoku.

Preferred occupations:
I am considering IT sales, planning,
other sales jobs, financial institutions,
and recruiting services.

NG Occupations:
I have no NG occupations.
```

Figure 3: Description of one student's wishes

Note that the primary purpose of this case study is to provide students with a list of company information, and we do not aim to automatically find a company that fully matches the student's preferences. Our tool lists multiple companies, which our technique extracts from 15,000 job postings; many of the students targeted in this study could be better at this extraction process and need help with a tool. The tools in this study will help assist such students with job placement guidance. We believe the tool that allows students to be presented with a list of potential companies through a short interview was useful.

3.1 Preprocessing: Extracting Workplace Locations and Job Types

We first obtained information from the students on their "preferences" and "things to avoid" about work location and job type. This information was obtained through open-ended questions; we show an example of the result in Fig. 3.

We use the morphological analyzer MeCab [11] to extract words related to place names and occupations. Then, we conduct a keyword search to find a match between the company profile text and student preferences.

To find a better match, after extracting proper nouns, such as the region's name, we add information on neighboring areas, considering the characteristics of the target student's preferences; especially, note that students like to get a job on

- XXX Corporation
  - **Tokyo**, Sendai, **Nagoya**, Osaka, Hakata, and 40 other locations. Miyagi, **Tokyo**, Nagano, **Aichi** (**Nagoya**), Osaka, and Fukuoka
  - Software, **Information** Processing, and **Information** **Services**. Development, sales, and maintenance of office equipment (**information** processing equipment) and systems. Listed on the first section of the Tokyo Stock Exchange. Flextime system available (core hours: 11:00-15:00). Telework system available. Clients include government agencies, **financial** institutions, etc.
  - **Sales jobs**, system engineers, customer engineers, technical staff, development, and research staff. A driving license is required for some positions.
  - (The rest of this job offer contains information on capitalization, annual sales, etc.)

Figure 4: Example of job opening

local orientation toward the Tokai region. For example, if the student wishes to work in "Nagoya," the neighboring districts "Aichi" and "Owari" are also used as keywords for the search. Similarly, in Fig. 3, the student has listed Hokkaido, Okinawa, and Shikoku as their least preferred work regions. These are not exact names of regions but rather broad regional names. Most of the place names in the job openings (typically, location of branch offices, factories, etc.) are city names. Therefore, for the three words "Hokkaido, Okinawa, and Shikoku," we will also add more detailed place names within the regions for matching, such as "Ehime, Asahikawa, Kagawa, Takamatsu, Kochi, Sapporo, Muroran, Matsuyama, Tokushima, Naha, Hakodate, and Kitami."

In finding a better match on job categories, because target students major in information technology, some search words are added before searching. For example, when "IT" appears in the description of desired items, the term "information" is also used.

On the other hand, to conduct a job matching, we created a dictionary with job information based on the information in the job posting, as shown in Fig. 4; such a posting contains information such as the location of the head office, the place of work, and the text of the company profile. In the example in Fig. 4, we underline the occurrence of words that match the student's desired information described above.

3.2 Calculating Two-Dimensional Trust Values

In this study, we calculated the degree to which words from the student's preferences appeared in the job postings for each work location and job type. For example, in the above case, the evaluation values are as follows[1]:

- The matching degree of location preference is 0.6; actually, 3 out of 5 words "Aichi, Tokyo, Owari, Hamamatsu, and Nagoya" as matching candidates match the job information; and
- The match level for job type is 0.8; 4 out of 5 possible matching words "information, sales, finance, recruiting, and service" match the job information.

In this study, we used the goodness of fit as trust values concerning the work location or the type of job. The trust level is the degree to which the text of the company profile matches the positive aspects desired by the student. The value is a real number between 0 and 1.

On the other hand, the distrust level was determined by whether or not the words that the students did not want appeared in the company profile. This decision is based on the fact that students tend to avoid firms whose profile contains items the students wish to avoid. This results in a distrust level of either 0 or 1.

In Fig. 3, the student listed Hokkaido, Okinawa, and Shikoku as the least preferred work locations. For the case of this student, the level of distrust regarding the work location is determined by whether or not the name of one of the following places or regions appears in the work location field of the job opening: Ehime, Asahikawa, Okinawa, Kagawa, Takamatsu, Kochi, Sapporo, Shikoku, Muroran, Matsuyama, Tokushima, Naha, Hakodate, Hokkaido, or Kitami. For the firm shown in Fig. 4, no such place name appears in the job opening. Thus, this student's distrust level concerning this firm is 0.[2] Therefore, the two-dimensional trust value about the workplace location of this firm is $(0.6, 0)$.

In the above matching, we calculated the trust and distrust levels independently. Therefore, there may exist inconsistencies in the trust and distrust levels. For example, for the two-dimensional trust value $(0.6, 0)$ above, we can calculate the degree of the discrepancy from a consistent trust value using Oda's fuzzy logical approach; the degree is $|(0.6 + 0) - 1| = |-0.4| = 0.4$. Also, we can calculate the observation point without inconsistency with Oda's reverse-item averaging method, and the result is $(0.8, 0.2)$; note that the first element of the pair is the integration value.

One can also obtain Marsh's one-dimensional trust value from the two-dimensional trust value, considering the observation point $(0, 1)$ as Marsh's score -1 and $(1, 0)$ as score 1, respectively. We can see the one-dimensional trust level as the "net trust value" obtained by subtracting the distrust level from the trust level. From the viewpoint of fuzzy logic, a one-dimensional trust value is a trust level without the inconsistency of evaluation, corresponding to the integration value[3].

In the above example, the distrust level is 0, so the first element of the pair $(0.6, 0)$ and the corresponding one-dimensional trust value 0.6 coincide. If the job offer includes a negative statement regarding the location of the job, the trust value

[1] Although we give an example in English, we actually search for Japanese keywords.

[2] Note that the job offer form also states "40 other locations," which may include specific locations the students do not wish to work at, although it is not specified. Only text matching was used in this study, and semantic analysis was not conducted.

[3] There is a difference in that the integration value ranges from 0 to 1, while the one-dimensional trust value ranges from -1 to 1.

- XXX Corporation $(0.8, 0.6, 451)$
  - Tokyo, Sendai, Nagoya, Osaka, Hakata, and 40 other locations. Miyagi, Tokyo, Nagano, Aichi (Nagoya), Osaka, and Fukuoka
  - Software, Information Processing, and Information Services. Development, sales, and maintenance of office equipment (information processing equipment) and systems. Listed on the first section of the Tokyo Stock Exchange. Flextime system available (core hours: 11:00-15:00). Telework system available. Clients include government agencies, financial institutions, etc.
  - Sales jobs, system engineers, customer engineers, technical staff, development, and research staff. A driving license is required for some positions.
- YYY Corporation $(0.6, 0.8, 2000)$
  - Tokyo Hamamatsu, Nagoya, and Osaka. Chiba, Tokyo, Kanagawa, Shizuoka, Aichi, Kyoto, Osaka, and Hyogo.
  - System design, construction, operation, maintenance, various software development, etc. We support IT infrastructure in a wide range of industries from finance, manufacturing, telecommunications, and services to space development. We provide solutions in various phases from system development, operation, and maintenance to infrastructure construction.
  - System Engineer.
- ZZZ Corporation Nagoya Branch $(0.6, 0.8, 1219)$
  - ...

Figure 5: Output result (partly)

would be 1. In this case, the two-dimensional trust value is $(0.6, 1)$, and the Marsh trust value is negative -0.4.

Similarly, for the job type, we defined the distrust level based on whether or not the job type the student does not want appears in the job offer text. Since the student's statement in the previous section states that "I have no NG occupations," the value of the distrust level is 0. Therefore, the two-dimensional trust value for the job category is $(0.8, 0)$.

3.3 Presenting a List of Recommendable Companies

Applying the above technique, we give trust values for work locations and job types for each job posting's entry. Then, we compute one-dimensional trust values to find a match between student and company profiles. Finally, a list of 20 job openings is presented to the student. Figure 5 shows an example of the output; actually, they are in Japanese. The list of the output is sorted in the order of:

1. one-dimensional trust value for job type,
2. one-dimensional trust value for work location, and
3. the number of employees of the company.

These elements are shown as a triple placed on the right-hand side of the company name.

In this study, we implemented the recommender system on Linux (Ubuntu 22). We used a set of job data in a CSV format with approximately 15,000 entries, extracted keywords, and converted them into a form Common Lisp could handle. The conversion was conducted with a shell script, using the morphological analyzer MeCab for natural language processing. For collecting students' preferences, we used Moodle. Students can describe their preferences in a free-style text format, and we extracted keywords such as work location or occupations from the text, and the resulting keywords were given to a Lisp program. Finally, the resulting Lisp program can calculate trust values and match the student's wishes and company profiles. We used Steel Bank Common Lisp (SBCL 2.1.11) in this study.

Our recommender system has presented some job openings that may not appropriately reflect the student's preferences; for example, some job offers contain work locations in foreign countries. However, the recommender system can present a sufficiently large number of job offers, and on the whole, the system gives a list of companies that match the student's preferences.

4 CONSIDERING CRITERIA FOR DISTRUST LEVELS

In our previous work [4, 5], we determined the trust level part of a two-dimensional trust value by accumulating positive factors. This study also collects favorable aspects of a firm's job openings for the trust level part of a two-dimensional trust value; that is, we increase the trust level when keywords that match the student's expectations appear in the company profile text.

On the other hand, we can see at least two types of cases in determining the distrust level. This section discusses how to determine the distrust level.

4.1 Case 1: Cumulative Distrust Level

The first approach is to determine the distrust level based on the cumulative degree of unfavorable evaluations, similar to the method used to determine the credibility level. The following is an example in [4].

Example 1 *In three countries, an opinion poll was conducted about the approval ratings of each country's governments. We used the following items to answer this question: "Do you trust your government?"*

1. *I have no idea;*
2. *Yes, I do;*
3. *No, I do not;*
4. *Sometimes yes, sometimes no.*

The number of answers for each item is $a_1^c, \ldots, a_4^c$ for country c; also, we have $s^c = a_1^c + a_2^c + a_3^c + a_4^c$. In this example,

we calculate the degrees of trust t_c and distrust d_c of the government with $t_c = \frac{a_2^c + a_4^c}{s^c}$ and $d_c = \frac{a_3^c + a_4^c}{s^c}$. A survey was conducted with 100 residents each in the countries of X, Y, and Z, and the following are the results:

$$\begin{array}{rcl}(a_1^X, a_2^X, a_3^X, a_4^X) & = & (10, 20, 30, 40),\\ (a_1^Y, a_2^Y, a_3^Y, a_4^Y) & = & (50, 30, 10, 10),\ \textit{and}\\ (a_1^Z, a_2^Z, a_3^Z, a_4^Z) & = & (20, 25, 5, 50).\end{array}$$

For each country, we can give the degrees of trust t_c and distrust d_c as follows:

$$\begin{array}{rcl}(t_X, d_X) & = & (0.6, 0.7),\\ (t_Y, d_Y) & = & (0.4, 0.2),\ \textit{and}\\ (t_Z, d_Z) & = & (0.75, 0.55).\end{array}$$

For each country we can also calculate the one-dimensional trust value i_c and the degree of inconsistency c_c[4]*:*

$$\begin{array}{rcl}(i_X, c_X) & = & (-0.1, 0.3),\\ (i_Y, c_Y) & = & (0.2, -0.4),\ \textit{and}\\ (i_Z, c_Z) & = & (0.2, 0.3).\end{array}$$

Suppose we define the two-dimensional trust values as in the approach of this example. In that case, the value of the distrust level gradually increases as the number of responses on items *3.* and *4.* in the questionnaire increases. In this sense, the distrust level is cumulative and takes various values between 0 and 1. We can see that the distrust level reaches extremities (i.e., values around 0 or 1) when either "almost all respondents answered with item *1.* or item *2.*, and the distrust level becomes around 0" or "almost all respondents answered with item *3.* or item *4.*, and the distrust level gets higher and becomes around 1." This consideration suggests that, in general, this method of determining the distrust level is unlikely to result in extreme values.

4.2 Case 2: Non-Cumulative Distrust Level

Another way to determine the distrust level is to rigidly set it to 0 or 1. In our previous study [5], we used such a distrust level in determining the authenticity of rescue requests in the event of flooding. This case concerns the determination of the distrust level in unusual circumstances.

During the torrential rainstorm in western Japan in 2018, many rescue requests were posted on SNS, and detailed address information on the posters appeared in some of those messages. Personal addresses are typically private information, and people regularly do not post them unnecessarily on SNS. Posting a private address indicates that the poster was really in imminent danger. Hence, the credibility of such a message as a rescue request becomes high.

[4]In this footnote, we provide a more detailed analysis for the pairs of (i_c, c_c). For country X, there is some degree of distrust of the government, and citizens in country X are somewhat confused since the degree of contradiction is positive. For country Y, the degree of trust exceeds the degree of distrust, but the degree of contradiction is negative, which suggests that the people have little interest in their government. For countries Y and Z, although their integration values are the same, the degree of contradiction is positive for country Z. Note that we can compare countries Y and Z, even though the conventional trust model cannot since the degree of contradiction is not addressed.

- I am the person who called for rescue after the heavy rain in Arii, Mabi-cho, Kurashiki City. I have just been rescued safely. Thank you very much for your concern. I will delete this tweet to avoid confusion. Thank you for your cooperation. #Kurashiki #Mabi-cho
- #Rescue completed #Kurashiki-shi, Mabi-cho, Arii XXX. We have received a report that they have been rescued safely. Sorry for your concern. Thank you so much.

Figure 6: Non-rescue requests containing (nearly) complete address information

However, in an emergency, when determining whether a message is a genuine rescue request, it is natural that the distrust level reaches maximum if there is even one suspicious element. Note that this approach to determining the distrust level differs from the cumulative approach used in the previous section.

Figure 6 shows some postings in the above disaster. In these messages, words such as "thank you" or "sorry for your concern" appear disproportionate to a rescue request. Therefore, the distrust level is set to 1, resulting in a low one-dimensional trust value. Such phrases typically appear in messages that report the completion of the rescue, citing past actual rescue requests.

For the application to job search assistance shown in this paper, we also set the distrust level to 0 or 1, considering students tend to avoid firms with "undesired items" because it may affect their later life. Summarizing, we can see the following:

- For the case of judging rescue requests in the event of flooding, we should employ a high distrust level to exclude information that would interfere with rescue because human lives are at stake; and
- For the case of job search assistance, students want to use a high distrust level since they wish to exclude any job information containing undesired conditions.

From this observation, we use the distrust levels at extremities (i.e., near 0 or 1) to vehemently reject information that is not appropriate for related parties, as in the case of the two examples listed in this section. In other words, this type of distrust determination method should be used when the impact of the failure is significant for the parties concerned. A detailed examination of the validity of this approach is a future issue.

5 DISCUSSIONS

In this study, trust values were obtained and used based on the company profiles' location and job type information. We have a further discussion on the application of this trust value in this section.

Although this study mainly focuses on preferences for work location and job type, some may question the influence of

other priorities, such as salary and company size. Although location and job type are not everything in job hunting, we chose these criteria in this case study because, in our experience, the target students tend to place importance on "location" and "job type." In reality, students decide which company to work for by considering other information, such as their impression of the company when they visit the company. We believe that it is possible to calculate the degrees of trust and distrust for other preference items.

This study independently treats the two types of preferences, i.e., work location and job type. In general, it isn't easy to automatically handle the interdependence of multiple preferences, and this paper's case study did not treat it. Consider the following example, in which the conditions for the location and job preferences are contradictory.

Example 2 *Please assume that the student's favorite place is Nagoya, his disliked place in Hokkaido, and his favorite job is software development. Also, please assume that the company has its headquarters in Nagoya and a software development center in Hokkaido.*

In this study, location preference and job type preference are treated independently. For this company, a location that the user dislikes (Hokkaido, Japan) is included in the job posting, and a high level of distrust is assigned to the site, so the company is either excluded from the list of companies to be presented, or presented at the end of the list. However, the final decision based on multiple preferences is made by the user, the student. One student may prioritize location preference, while another may be more concerned about the type of job. Since there may be other criteria, we believe that it is difficult to make this decision automatically. Therefore, this study treated the evaluation results (i.e., one-dimensional trust values) for work location and job type independently and presented them together.

A one-dimensional trust value based on trustworthiness alone may not compare the trust values of job postings from two companies, or it may result in a company that the student does not want to remain on the list of companies. We consider the following example.

Example 3 *Assume that the student showed three favorite places. Also, assume that a company showed just the same three places. Another company showed ten sites, including the three places.*

In this example, since the same values are computed for the positive part of trustworthiness, the job postings are incomparable only when dealing with the positive trust levels. However, when we consider the distrust levels, the corresponding one-dimensional trust of the locations of these companies may have different values. If the second firm has an undesired location among the seven remaining sites, the one-dimensional trust value will be lower[5]. Since this study treats distrust independently, comparing two firms that do not differ only in this evaluation of trustworthiness is possible.

[5]Suppose the remaining seven workplaces do not include the unwanted workplaces. In that case, the student can either ignore the seven workplaces as "workplaces that the student does not refuse," or he can re-enter the unwanted workplaces and re-create the list again using the tool in this study.

While this study delves into the intricate realm of evaluating corporate information using two-dimensional trust values, some readers may be tempted to compare these findings with the more conventional method proposed by Marsh et al. In reality, however, it is not easy to do so. Our previous study [4] showed that Marsh et al.'s one-dimensional trust values correspond to the case where we allow a strong restriction: "The sum of trustworthiness and distrustworthiness is exactly one in a two-dimensional trust representation." This result means that when we make the same evaluation as in the present experiment using 1D trust values, we should assume that students have in their minds 1D trust values that satisfy the condition of the definite sum; for example, the trust value of a company's job information is 0.76, and the distrust value is 0.24, and these values can be correctly quantified. However, making such an assumption is difficult, at least in applications like the one treated in this study. In this study, we do not assume such a sum scale but allow for ambiguity regarding people's level of trust in and distrust of the target. By obtaining "trustworthiness" and "distrustworthiness" for each of the items of work location and job type from "degree of conformity with expectations" and "presence or absence of unwanted items," respectively, it can be said that this study approximates "the true trust value in the minds of students" regarding corporate information. Although these approximated values do not always satisfy the conditions of the definite sum, by calculating the integrated value, "the evaluation value based on the two-dimensional trust theory is translated into the evaluation value of the one-dimensional trust theory." As a result, the evaluation value of the definite sum scale, which is difficult for people to answer directly, is objectively obtained.

In addition to this, the question of whether it is appropriate to treat students' occupational preferences with a trust concept may also arise. In this study, the observer is a student, and the trustee is job information; note that in the trust theory, the trustee is not necessarily a person. Following the definition of the trust concept in section 2.1, the trust value (after being converted to a one-dimensional value) holds a pivotal role. It corresponds to the degree to which the student believes the job information. When the trust value is sufficiently high, it fosters a strong belief in the students, leading to a positive perception of the job information. When the one-dimensional trust value is negative, the student believes some of the job information may work against the student in the job-hunting situation. Actually, including unacceptable information may work against the student. Furthermore, when the evaluation result shows an "untrusted" case, the evaluator cannot determine whether the job information is trustworthy enough to adopt. In summary, the trust value represents "whether the given job information is desirable to the student." Therefore, evaluating students' job preferences using trust theory is appropriate, and we can see that it is a good application.

6 CONCLUSION

This study treated the job-matching problem as a practical application of the two-dimensional trust model. The definition of the two-dimensional trust value presented in our previ-

ous study (or Section 2) described how to determine the range of trust/distrust values and calculate the integration value, which corresponds to Marsh et al.'s one-dimensional trust value. However, it did not specify how to determine the values of trust and distrust levels in specific cases. Therefore, this paper has presented the job-matching problem as a concrete example of using these values, especially for applying distrust in an emergency. We also have shown how to determine the distrust level in the job matching problem. We assigned 0 or 1 instead of any value between 0 and 1 to reject information that is not appropriate for the student vehemently. Furthermore, we discussed how to determine the distrust level in two possible cases (cumulative distrust level and non-cumultive distrust level), paying particular attention to the similarities with the case of message classification in the event of flooding. A two-dimensional trust that considers the distrust level can be used to compare two companies that cannot be compared only based on trustworthiness or to eliminate inappropriate information using the distrust level.

We developed a recommender system for students' job-finding assistance. After collecting information on job openings and student preferences, we calculated the two-dimensional trust values that represent the fitness of matching between the student and the company. However, the two-dimensional trust value may be inconsistent since the trust and distrust parts are given independently. This study obtained a corresponding one-dimensional trust value for a consistent evaluation; specifically, we got the one-dimensional trust value by calculating the integration value of Oda's FCR method. Then, we employed the resulting trust value in the recommendation process. In this study, we also discussed determining the distrust levels.

This paper uses a coarse criterion that we only use, either 0 or 1, to determine the distrust level. As indicated in this paper, there are cases where this idea is sufficient as a criterion of distrust. However, under this criterion, although it is possible to "reject" messages containing inappropriate information, it is difficult to "finely discount" the messages' trust level. Hence, introducing a finer (i.e., not too coarse) evaluation of distrust levels as future work is essential. A trust concept called swift trust [12, 13] is necessary for building cooperative relationships between victims and volunteers during a large-scale disaster [14–16]. We believe the idea of not-too-coarse distrust levels helps evaluate the swift trust. It is also necessary to provide criteria for which type of distrust we should employ in which situations. It is also an interesting issue.

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