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Invited Paper

Considerations on Risk Communication for IT Systems and Development of Support Systems

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Abstract: Many of society's systems are dependent on information technology (IT), which means that securing the safety of IT systems is of the utmost importance. Furthermore, numerous stakeholders (managers, customers, employees, etc.) exist in the risk measures decision-making process for these IT systems, which makes it necessary to have a means of communicating risk measures so that stakeholders can easily form a consensus when necessary. For this purpose, we have developed a Multiple Risk Communicator (MRC) to assist in consensus formation within organizations and a Social-MRC system to support social consensus formation, which we have applied to various problems. This paper describes the considerations that IT system risk communication should take, describes the development of the necessary support systems, and provides information on the results of their application.

Keywords: IT Risk, Risk Communication, Risk Management, Support Systems

1. Introduction

Functions such as finance, airports, railroads, power and gas utilities, government and administrative services, medical care, water utilities, and logistics are critical infrastructure to society and the loss of any of these functions would have major social impacts. Many social mechanisms, including the above critical infrastructure, are increasingly dependent on information technology (IT) systems, which means that if their IT systems were to stop functioning, it would have a tremendous impact on social activities.

Considering their increasing importance, it is insufficient to secure the safety of IT systems through conventional information security measures. In the first place, it is necessary to consider encompassing potential problems such as natural disasters, hardware malfunctions, software bugs, and human errors, in addition to intentional wrongdoing. Secondly, it is necessary to take an integrated approach to handling the following three layers of safety:

(1) Safety for IT systems themselves
(2) Safety for information handled by IT systems
(3) Safety for services performed by IT systems

In this paper, we use the term "IT risk" when referring to the possibility that the safety of an IT system could be compromised [1].

Because numerous stakeholders (managers, customers, employees, etc.) are involved in the decision-making process for IT risk measures, it is necessary to have a means of risk communication that ensures that they can easily form a consensus. In such cases, there are three purposes for risk communication:

(a) personal choice
(b) consensus formation within organizations
(c) social consensus formation

Of the three, there is a particular need to develop tools that support risk communication for (b) consensus formation within organizations and (c) social consensus formation. In response to this need, we developed a Multiple Risk Communicator (MRC) for consensus formation within organizations and a Social-MRC system to support social consensus formation, which we have applied to various problems.

In this paper, we first consider the potential shape of IT risk communication, and then describe the development of two support systems for risk communication, MRC and Social-MRC, and show the results of their application. The two characteristics shared by MRC and Social-MRC are described below:

Characteristic 1: A measure to reduce one risk often gives rise to other risks. Accordingly, it is necessary to resolve issues for multiple risks.

Characteristic 2: When considering measures for IT systems, it is difficult to achieve objectives by applying single measures alone. Accordingly, it is necessary to have a system that seeks the optimal combination of measures.

The importance of risk communication itself is widely recognized, and risk communication and research have been attempted for various issues relating to nuclear power generation, the environment, health and medical care, and food safety (see Ref. [2]). However, aside from this research, there has been almost no research on risk communication for IT systems, even though there are a number of research examples that have presented information system use in support of risk communication, as summarized in Ref. [3]. These include, for example, a system that supports the mutual understanding, learning, and mutual consideration of people in diverse positions through the construction of a Web system [4]. However, we are not aware of any other papers that describe a system to support risk communication for IT systems, as

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described here. Furthermore, among the research that has been conducted for reasons other than IT systems, no approaches have considered opposing risks to support consensus formation on the optimal combination of proposed measures.

When considering the above, it is clear that most of the considerations that shape risk communication for IT systems are described for the first time in this paper. We have reported on our support system developments and application results in other papers [5], [6], [7], [8], [9], [10], [11], [12], [13]. In this paper, we summarize this information, describe the development of a new Social-MRC program, and show the results of its application.

2. Consideration Related to Risk Communication for IT Systems

2.1 Overview of Risk Communication

Research on risk communication is considered to have begun in earnest in the 1980s. In 1989, the US National Research Council (NRC) defined risk communication as "an interactive process of exchange of information and opinion among individuals, groups, and institutions." The definition includes "discussion about risk types and levels and about methods for managing risks." Risk communication shares roots with civil rights as a pillar of democracy, as much as the right of self-determination, the right to know, accountability, informed consent, and information disclosure. It is based on the principle that a suitable consensus can only be obtained by properly communicating information to citizens.

The importance of risk communication itself is widely recognized and risk communication has been variously attempted for issues related to nuclear power generation, the environment, health and medical care, and food safety (see Ref. [2]). However, there have been very few attempts at risk communication for IT systems. As the safety of society can be expected to become increasingly dependent on IT systems in the future, risk assessment for IT systems, together with risk communication, can be expected to grow in importance as well.

2.2 Types of Purposes of Risk Communication

Risk communication and consensus formation has three purposes, which are outlined below.

(1) Personal choice. The purpose here is to permit individuals to examine risk information in order to make decisions about what actions to take. For example, risk communication is often conducted between specialists and citizens, such as in regard to making a personal decision to quit smoking, or whether to get vaccinated if there are concerns about side effects. The means of communication can include mass media (newspapers, television, etc.), pamphlets, and Web content, as well as direct education such as safety courses, including via e-learning.

(2) Consensus formation within organizations. The purpose here is to determine the measures that should be taken by an organization, such as a corporation. For example, persons operating a plant may need to decide what kind of environmental protection measures to take. Such risk communication is conducted centering on stakeholders within the organizations and by inviting some outside stakeholders to share their views.

(3) Social consensus formation. The purpose here is to decide what actions should be taken by society as a whole. For example, risk communication is needed in order to decide on the advisability of restarting nuclear power plants, or to inspect all cows for mad cow disease (BSE). Such communication is often conducted in the form of public hearings and consensus meetings. While consensus within organizations may only involve several stakeholders, social consensus formation involves at least several thousand participants.

2.3 Characteristics of Risk Communication for IT Systems, and Support Systems

We analyzed the IT risks related to various problems such as the year 2000 problem and issues regarding personal information leakage, cyber terrorism, encryption failures, and malfunction of large-scale information systems [1]. The results of our analyses showed that IT system risks had the following characteristics in common with the risks of other systems.

(1-1) It is necessary to respond to multiple risks

Responses to one risk often triggers other risks, as in the case of adopting bio-ethanol for energy measures, which has led to food shortages. Accordingly, it is also essential to consider opposition of risks or multiple risks in relation to IT systems. **Figure 1** shows the relationship between security and privacy. As shown here, security and privacy risks can be either compatible or in conflict. For example, encryption is used as a security measure and public key certificates are used for digital signatures, but the addresses and birth dates contained in these measures can lead to the release of personal information, which can then become a privacy issue.

(1-2) It is important to engage in risk communication with multiple stakeholders.

As shown in **Fig. 2**, technology can contribute to resolving risks that are in opposition in situations where one measure improves both security and privacy. For example, if the use of public key certificates as a security measure causes personal information leakage and thus becomes a privacy issue, it is possible to distribute certificates that only describe attributes (in place of public key certificates), which is desirable for both security and privacy. However, compared with the use of public key certificates, attribute certificates are somewhat less safe and are not as convenient. Accordingly, the choice of which solution to take is ultimately up to the preferences of the stakeholders involved in

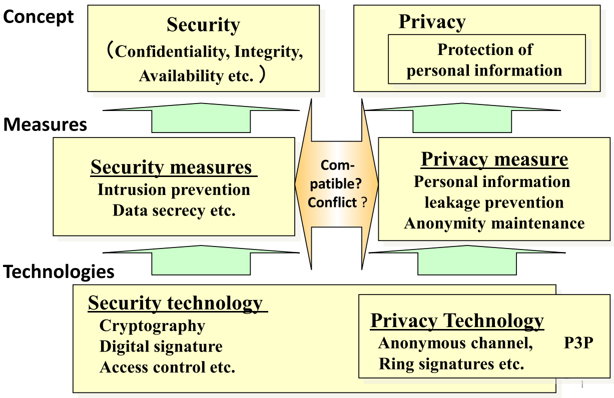


Fig. 1 Relationship between security and privacy.

Table 1 Types of issues for IT risk communication.

	Examples of Risk Communication for Other Fields	Examples of Risk Communication in IT			Support System
		IT System Itself	Information Handled by IT System	Service Performed by IT System	
Purpose 1: Personal choice	Implementation of smoking ban Influenza vaccinations	Security hole measures for individual PCs	Confidentiality measures for own information in social network services	Measures for safe downloading of application software for smartphones	ELSEC tool to support e-learning
Purpose 2: Consensus within organizations	Environmental measures at factories	Data backup measures for business continuity plans	Measures to prevent personal information leakage in offices	Securing of quality method of the product to treat in net shopping	Multiple risk communicator (MRC)
Purpose 3: Social consensus	Advisability of restarting nuclear power plants Inspection of all cows for mad cow disease (BSE)	Advisability of assigning national identification numbers	Advisability of information filtering for children	Advisability of the sale of medicine using net shopping	Social-MRC system to support social consensus formation

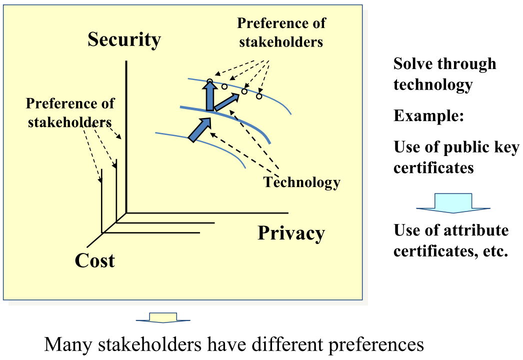

Security
Preference of stakeholders
Preference of stakeholders
Technology
Privacy
Cost
Solve through technology
Example:
Use of public key certificates
Use of attribute certificates, etc.
Many stakeholders have different preferences

Fig. 2 Method of resolving opposing risks.

the decision-making process.

Next, we found that IT systems had the following characteristics when compared with other risks.

(2-1) For IT risk measures, it is difficult to respond by applying single measures alone, which makes it necessary to combine various measures.

IT systems achieve diverse functions through software, so a failure also has diverse impacts. Furthermore, since IT risks also encompass intentional wrongdoing, the threat increases as the wrongdoing becomes increasingly sophisticated. This makes responding difficult. Accordingly, it is difficult to prevent the IT risks by applying single measures alone, which means that it is essential to combine various measures.

(2-2) There is strong demand for risk communication for the sake of consensus formation within organizations.

While only a limited number of organizations operate nuclear power plants, almost all organizations use IT systems. Accordingly, even though there are few organizations where internal consensus is needed on risk communication in a nuclear power plant, it is relatively important to have a social consensus. By comparison, broad requirements exist for both social and organizational consensus formation in IT system risk communication.

Therefore, we examined risk communication issues that could exist in the future for IT systems by separately considering the aforementioned issues (personal choice, consensus formation within organizations, and social consensus formation) and three risks specific to IT systems (the IT system itself, information handled by the IT system, and services performed by the IT system), as summarized in **Table 1**.

For Purpose 1 (personal choice), risk information exchange is necessary for individuals who will decide on responses that should be taken against the risk. For IT, measures include (a) security measures for their personal computers, (b) confidentiality measures regarding personal information on social network services, and (c) measures that ensure safe downloading of application software for smartphones. The information sender can be a government agency such as the Information Technology Promotion Agency (IPA) or a company involved in security, while the recipient is the owner or user of the IT equipment, such as a service recipient. The risk communication is aimed at preventing users from becoming victims, and emphasizing the damages and other impacts that could occur if suitable actions are not taken. The risk communication typically takes the shape of education or efforts to raise awareness and it is often necessary have e-learning to support these activities. Accordingly, the authors have developed the ELSEC tool to support the authoring of e-learning content [5].

For Purpose 2 (consensus within organizations), the persons that make up the organization should also give consideration to outside persons, such as users, when forming a consensus on risk measures. The IT measures normally include (a) data backup measures for business continuity plans, (b) measures to prevent personal information leakage in offices, and (c) methods for securing the quality of products such handled through online shopping.

The phase for deciding what measures to take is critical, and there is a strong requirement to link it to quantitative assessment. The risk communication is often conducted between the stakeholders within the organization and either a representative of outside persons such as users or role players. When seeking measures for adoption, consideration is given to the fact that applying only a single measure often gives rise to other risks, as well as the issues of costs and ease of use. Furthermore, since IT systems have diverse functions, it is difficult to respond by applying single measures alone, which makes it necessary to seek a combination of proposed measures. In order to support this risk type of communication, we developed an MRC that satisfies the aforementioned requirements and applied the system to measures for personal information leakage and internal control issues [6]. The MRC is described in detail in Section 3.

Purpose 3 (social consensus) is often conducted in relation to IT and is often tied to the enactment or revision of legislation. Examples include (a) the issue of assigning national identification numbers and enactment of legislation to criminalize the creation of computer viruses, (b) advisability of information filtering for children, and (c) the advisability of medicine sales via online shopping. Such consensus formation is characterized by the existence of numerous stakeholders, which makes it a major challenge to find ways to incorporate the opinions of many opposing stakeholder viewpoints. Therefore, risk communication for social consensus is often not based on quantitative assessment, but on quantitative analysis such as in the case of risk communication using the MRC. In attempting to apply the latter approach, the social consensus formation involves at least several thousand participants, compared with only several stakeholders for consensus within organizations. To fulfill these requirements, we developed the Social-MRC system to support social consensus formation. This system offers integrated support of risk communication comprising the layer of communication between opinion leaders and a layer of communication that reflects the involvement of ordinary stakeholders [7]. The Social-MRC is described in detail, together with the results from trial application of the system, in Section 4.

3. Development and Application of MRC System to Support Risk Communication for Consensus within Organizations

3.1 Requirements for Development of MRC and Overview of System

The requirements for the development of an MRC are as shown below (**Fig. 3**):

Requirement 1: Many risks exist in IT systems including security risks and privacy risks. Accordingly, it is necessary to have a means of avoiding conflict among risks.

Requirement 2: When considering measures for IT systems, it is difficult to achieve objectives by applying single measures alone. Accordingly, it is necessary to have a system that seeks the optimal combination of measures.

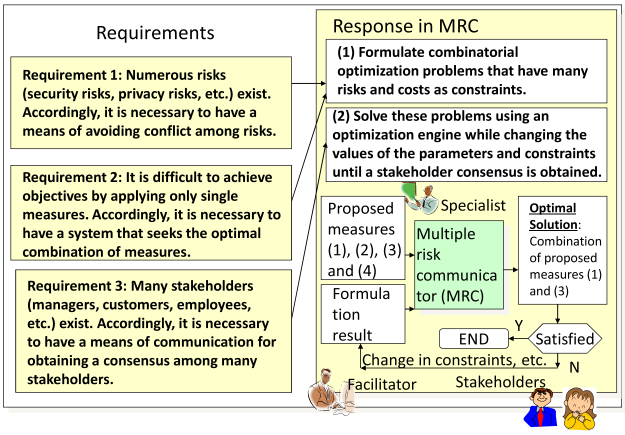

Requirements
Requirement 1: Numerous risks (security risks, privacy risks, etc.) exist. Accordingly, it is necessary to have a means of avoiding conflict among risks.
Requirement 2: It is difficult to achieve objectives by applying only single measures. Accordingly, it is necessary to have a system that seeks the optimal combination of measures.
Requirement 3: Many stakeholders (managers, customers, employees, etc.) exist. Accordingly, it is necessary to have a means of communication for obtaining a consensus among many stakeholders.
Response in MRC
(1) Formulate combinatorial optimization problems that have many risks and costs as constraints.
(2) Solve these problems using an optimization engine while changing the values of the parameters and constraints until a stakeholder consensus is obtained.
Specialist
Proposed measures (1), (2), (3) and (4)
Formula tion result
Multiple risk communica tor (MRC)
Optimal Solution: Combination of proposed measures (1) and (3)
Y
END
Satisfied
N
Change in constraints, etc.
Facilitator
Stakeholders

Fig. 3 Overview of multiple risk communicator.

Requirement 3: Numerous stakeholders are involved in decision making for IT systems (managers, customers, employees, etc.). Accordingly, it is necessary to have a means of communication that facilitates obtaining a consensus among those stakeholders.

The MRC that we developed for these requirements formulates combined optimization problems (also called "optimal combination problems") that have many risks and costs as constraints, in order to fulfill Requirements 1 and 2. The MRC solves these problems using an optimization engine while changing the values of the parameters and constraints until a stakeholder consensus is obtained, in order to fulfill Requirement 3. Therefore, we developed our MRC with a function that displays these results in an easily understandable manner.

The MRC program was implemented using Java and PHP in a Windows XP environment. The total number of coding steps was approximately 10,000. The MRC was configured with the following: an input and output function for specialists, a computing function, a stakeholder support function, an overall control function, a database function, and a negotiation infrastructure. The users of this MRC were envisioned to be MRC specialists, multiple decision-making stakeholders, and facilitators who would mediate among these parties.

For application of the MRC, the MRC specialist acts in advance to secure the cooperation of specialists in the problem, expecting that the following response will be taken. The MRC specialist is a person who analyzes the problem that the MRC is applied to, and formulates it as an optimal combination problem for the proposed measures, while operating the MRC to seek the optimal combination.

Phase 1—The MRC specialist makes the following advance preparations for inputting data into the MRC program.

1. Decision on the problem to be solved: Decide on the problem that must be dealt with, such as at the demands of people who want the problem to be solved. Examples include a problem involving personal information leakage at a local government.

2. Analysis of the problem: Analyze the causes of the problem, method of wrongdoing, etc. Examples include the clarification of routes and methods by which information was removed.

3. Stakeholder decisions: List the stakeholders who are impacted by the decision-making process. For a local government, the stakeholders can be senior government officials, citizens, or

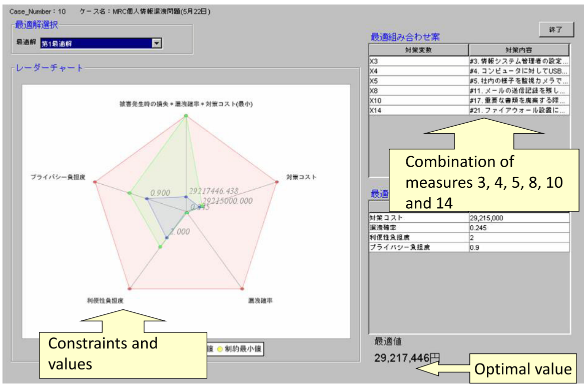
government workers. Ask the stakeholders to give their opinions through the risk communication process.

4. Decision on the objective function and constraints: Decide the objective function and constraints for formulating the combined optimization problem. This is done to seek the optimal combination of proposed measures. The objective function here is to minimize the total social cost, which represents the total loss to society. For constraints, we used items that are of interest to each group of stakeholders. For example, we set the objective function as (Probability of personal information × Amount of damages + Cost of measures). We set the following constraints: cost of measures for senior government officials, probability of personal information leakage for citizens, privacy burden, and convenience burden on government workers, for a problem involving personal information leakage at a local government.

5. Listing of proposed measures and estimation of related parameters: List the proposed measures that are considered to be effective. For example, "surveillance by obtaining externally sent email" for Proposed Measure 1, "prohibit removal of PCs" for Proposed Measure 2, and "adopt an access management system for isolated areas" for Proposed Measure 3. Next, decide on the measures to adopt using a questionnaire or by adding up the cost or burden of the proposed measures, such as the cost of each proposed measure, privacy burden, and convenience burden. Organize these results in a table. Use a Fault Tree Analysis (FTA) to determine the probability of personal information leakage if the measures are taken, ensuring that the data required for FTA is also prepared in advance.

Phase 2—The specialist takes the data that was obtained during the advance preparations and inputs it into the MRC program. The MRC program then performs the optimization calculation and displays the results. **Figure 4** shows a screenshot of the output results.

Phase 3—The facilitator gathers the stakeholders. The specialist explains the premises for the formulation and presents the results that were obtained using the MRC program by means of a projector or similar tool. The stakeholders view these results while voicing their opinions, such as "There are other possible measures" or "The constraints values are wrong." These opinions are incorporated and the data is reentered into the MRC to calculate a solution using the new constraints. This process is continued until the stakeholders reach an overall consensus.



Case_Number：10　ケース名：MRC個人情報漏洩問題(5月22日)

最適解選択

最適解　第1最適解

最適組み合わせ案

対策変数	対策内容
X3	#3. 情報システム管理者の設定...
X4	#4. コンピュータに対してUSB...
X5	#5. 社内の様子を監視カメラで...
X8	#11. メールの送信記録を残し...
X10	#17. 重要な書類を廃棄する際...
X14	#21. ファイアウォール設置に...

対策コスト	29,215,000
漏洩確率	0.245
利便性負担度	2
プライバシー負担度	0.9

最適値

29,217,446円

Combination of measures 3, 4, 5, 8, 10 and 14

Constraints and values

Optimal value

Fig. 4 Output from MRC program.

The MRC mechanism and method of application are described in further detail in Ref. [6].

3.2 MRC Application and Assessment

We applied the MRC to ten cases centering on problems involving personal information leakage [6], [8], including personal information leakage measures by Tokyo's Setagaya Ward government office. The other cases included problems with internal control [9] and digital forensics [10]. We confirmed that a consensus was reached in nine out of ten cases, which exceeded our expectations. The consensus was obtained as a result of the participants developing greater trust through the discussion process, and their realization that, despite their differing individual opinions, there was much in common between the proposed measures covered by the combination of proposed measures to be adopted. In addition, even when all the participants were not actual stakeholders in the decision-making process, but included some role players (such as ordinary citizens), a consensus was obtained by taking into consideration the expected opinions. Furthermore, many of the decision-making stakeholders were of the opinion that the consensus formation results were useful, which we did not initially expect.

From 2009 to 2011, we taught the MRC each year to a total of 34 master's degree students in information processing and asked them to apply the process. Eight students participated in a questionnaire survey that we conducted in 2009. An analysis of the questionnaire results showed the average time required to obtain a solution using MRC was 13.7 hours. Although these results indicated that there was further room for improving the ease of use, the average level of satisfaction expressed regarding the solutions obtained and the assessment average of their effective use was more than four points, with five points designated as a perfect score [11].

4. Development of Social-MRC System to Support Social Consensus Formation and Application

4.1 Background of the Development

In order to form a social consensus, it is necessary to enable more people to participate in consensus formation, and to reflect their opinions to the greatest extent possible. However, while it is desirable to enable more than several thousand people to directly use the MRC, this is very difficult to accomplish. Therefore, we decided to adopt an indirect democratic method that is used in actual politics. Under this method, opinion leaders discuss their opinions on the problem to be solved. Ordinary stakeholders, who express their opinions and indicate which opinion leader they support, simultaneously view the discussion. This approach offers the advantages outlined below.

(1) It is possible to ascertain, in real time, the trend of opinions among ordinary stakeholders, which makes it is easier to avoid the problem of opinion leaders clinging to their own opinions and thus preventing a consensus from being formed.

(2) Outstanding opinions from among the opinions of ordinary stakeholders are reflected in the decision making. This makes it

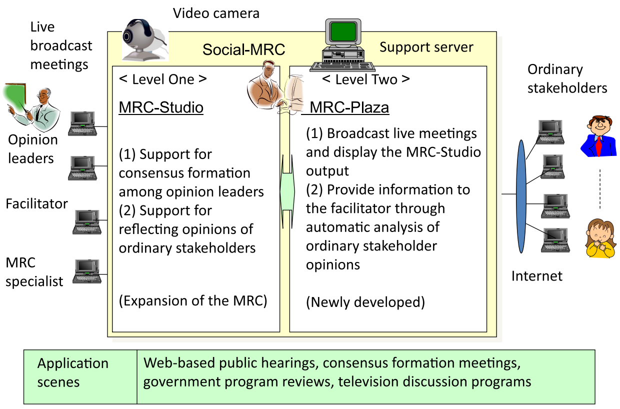

Live broadcast meetings
Video camera
Social-MRC
Support server
< Level One >
MRC-Studio
< Level Two >
MRC-Plaza
Ordinary stakeholders
Opinion leaders
(1) Support for consensus formation among opinion leaders
(2) Support for reflecting opinions of ordinary stakeholders
(1) Broadcast live meetings and display the MRC-Studio output
(2) Provide information to the facilitator through automatic analysis of ordinary stakeholder opinions
Facilitator
MRC specialist
(Expansion of the MRC)
(Newly developed)
Internet
Application scenes
Web-based public hearings, consensus formation meetings, government program reviews, television discussion programs

Fig. 5 Overview of Social-MRC.

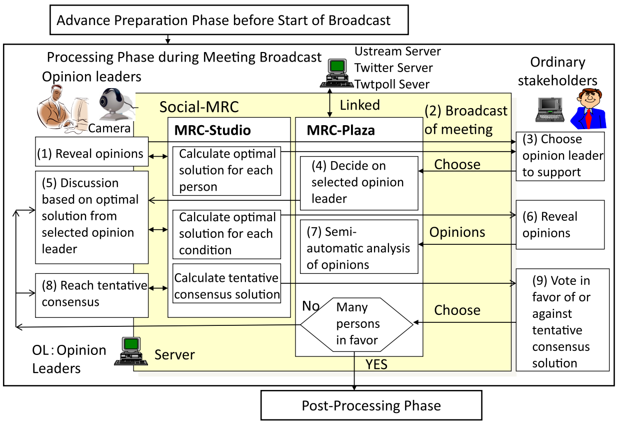

Advance Preparation Phase before Start of Broadcast
Processing Phase during Meeting Broadcast
Ustream Server
Twitter Server
Twtpoll Sever
Ordinary stakeholders
Opinion leaders
Social-MRC
Linked
(2) Broadcast of meeting
Camera
MRC-Studio
MRC-Plaza
(1) Reveal opinions
Calculate optimal solution for each person
(4) Decide on selected opinion leader
Choose
(3) Choose opinion leader to support
(5) Discussion based on optimal solution from selected opinion leader
Calculate optimal solution for each condition
(7) Semi-automatic analysis of opinions
Opinions
(6) Reveal opinions
(8) Reach tentative consensus
Calculate tentative consensus solution
No
Many persons in favor
Choose
(9) Vote in favor of or against tentative consensus solution
OL: Opinion Leaders
Server
YES
Post-Processing Phase

Fig. 6 Operating procedures for Social-MRC.

easier to obtain a solution that is superior to those based on the original opinions of the opinion leaders.

To achieve these objectives, we developed the concept of the Social-MRC system to comprehensively support two-level risk communication, comprising communication between opinion leaders at one level and communication with ordinary stakeholder participation at another level. **Figure 5** shows an overview of the system.

Opinion leaders here are persons who represent opinions from separate standpoints on the problem to be solved. The facilitator is the person who conducts the meeting and supports the participants' consensus formation. The MRC specialist analyzes the problem to be solved and formulates it as an optimal combination problem while using MRC to calculate a solution, which is displayed for the opinion leaders, facilitator, and ordinary stakeholders. Ordinary stakeholders are persons with an interest in the problem to be solved and who are qualified to participate in the meeting. It is also possible to open up the meeting so that anyone can participate. Additionally, there can be a director to support the facilitator.

As shown in Fig. 5, the Social-MRC consists of MRC-Studio and MRC-Plaza. For the first level (communication between opinion leaders), we used the previously developed MRC and added necessary features, which we then named MRC-Studio. For the second level (discussion with ordinary stakeholder participation), we developed MRC-Plaza and broadcasted the discussions between opinion leaders to ordinary stakeholders using the video sharing features of Ustream while simultaneously displaying the output from MRC-Studio from the perspective of opinion leaders. We also asked ordinary stakeholders to voice their opinions and displayed their opinions for opinion leaders in an easily comprehensible way.

Topics that Social-MRC was initially deemed suited to handle include the following: (a) the issue of assigning national identification numbers and the advisability of criminalizing the creation of computer viruses, (b) advisability of information filtering for children, and (c) legal effectiveness of an electronic signature law. Other suitable topics included the issue of surveillance cameras and privacy, and the issue of blocking child pornography. Possible applications for Social-MRC include Web-based public hearings, consensus meetings, and televised discussion programs.

Social-MRC is intended to be used when more thorough discussion and rapid consensus formation is desired than is possible through conventional means. In such circumstances, Social-MRC is useful for mutual information exchange because it incorporates the opinions of stakeholders (such as citizens), instead of one-sided exchange, to decide policy while confirming impact of changing parameters on the overall situation.

4.2 Social-MRC Operation Method

The following are the procedures for using Social-MRC to obtain consensus formation on IT risk measures (**Fig. 6**).

Advance Preparation Phase before Start of Broadcast

(1) The meeting organizer determines, in advance, the problem to be solved and decides on the opinion leaders.

(2) The MRC specialist secures the cooperation of persons who are knowledgeable about the problem to be solved and formulates it as a combined optimization problem. The specialist then inputs the parameters and constraint values into MRC-Studio and runs a calculation to determine the initial solution for the optimal combination of measures.

(3) The MRC specialist shows the results from application of MRC-Studio to the opinion leaders and adds proposed measures, or changes the parameter and/or constraint values, using MRC-Studio, in an effort to seek the optimal combination of proposed measures for each opinion leader.

Processing Phase during Meeting Broadcast

1. Each opinion leader expresses his or her opinion, and explains the constraint values that he or she set along with the optimal solution that was obtained using MRC-Studio.

2. This process is recorded using TV cameras. The functions of Ustream are incorporated into MRC-Plaza for broadcasting via video and audio, and the output screen from MRC-Studio is then incorporated into MRC-Plaza and broadcast to ordinary stakeholders.

3. Ordinary stakeholders choose whose optimal solution they think is most desirable.

4. These results are made known to the facilitator and opinion leaders via MRC-Plaza and MRC-Studio. The discussion is subsequently advanced based on the combination of proposed measures from the opinion leader who received the most support ("selected opinion leader").

5. Each opinion leader points out problems with the combina-

tion of proposed measures chosen through the above process, or points out differences in the parameter values and constraints in advancing the discussion.

6. This discussion process is broadcast to ordinary stakeholders, as in Step 2. Ordinary stakeholders perform the following: (a) indicate which opinion leader's opinion is closest to their own opinion, (b) point out problems with either the proposed measures being discussed or the combination of proposed measures, and (c) point out facts that are not being recognized.

7. These opinions are sent to MRC-Plaza using the functions of Twitter. MRC-Plaza (semi-)automatically analyzes the opinions that are supported by numerous people and important opinions, and conveys the results to the facilitator and opinion leaders.

8. Under the moderation of the facilitator, the selected opinion leader takes into consideration the response from ordinary stakeholders and opinions of other opinion leaders, and then approves changes to the parameters and constraint values related to the effectiveness of the measures. The MRC specialist uses the optimization engine in MRC-Studio to calculate and display the optimal combination of proposed measures. Demands from multiple opinion leaders can also be incorporated when running the calculations. Once the opinion leaders reach a consensus through this process, it is taken to be a tentative consensus solution and the process advances to Step 9. In other cases, the process returns to Step 5.

9. When the opinion leaders have reached a tentative consensus solution, ordinary stakeholders are asked if they support this solution (as in Step 2). The selection can be done with the involvement of ordinary stakeholders. This is repeated until there is a majority of support for the solution or a deadline is reached. In other cases, the process returns to Step 5, and the same process is carried out by incorporating the wishes of ordinary stakeholders.

Phase for Arrangements after Broadcasting

(1) The results of the tentative consensus among opinion leaders and consensus formation that received the most support from ordinary stakeholders are linked to specific measures.

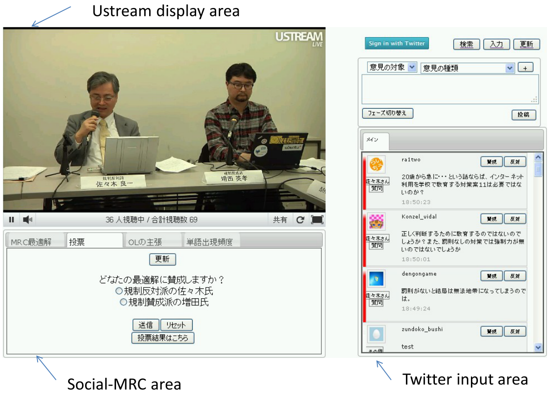
(2) The MRC specialist or facilitator analyzes the process for application of Social-MRC, and summarizes the know-how for use in a future application.

(3) If a deadline is reached without forming a consensus, the organizer schedules an additional meeting.

4.3 Development of Social-MRC Program

We developed a simple prototype of the Social-MRC program [7] and experimentally applied it to the problem of information filtering for children [13]. We then incorporated the results from this testing into the development of the full Social-MRC program. We also developed MRC-Studio to improve on the existing MRC and modified it so that MRC-Plaza could view the results from calculating the optimal solution for individual cases by means of XML files. The following is an overview of MRC-Plaza.

(1) We developed MRC-Plaza to allow it to be displayed in a Web browser. **Figure 7** shows how the screen is composed of a Ustream display area, a Twitter input area, and a Social-MRC area.



どなたの最適解に賛成しますか？
○規制反対派の佐々木氏
○規制賛成派の増田氏

ra1two
20歳から急に・・・という話ならば、インターネット利用を学校で教育する対策案11は必要ではないのか？
18:50:23

Konzel_vidal
正しく判断するために教育するのではないのでしょうか？また、罰則なしの対策では強制力が無いのではないでしょうか
18:50:01

dengongame
罰則がないと結局は無法地帯になってしまうのでは。
18:49:24

zundoko_bushi
test

Fig. 7 Sample screenshot of output from MRC-Plaza program.

(2) As shown in the right part of the screenshot in Fig. 7, we improved the Twitter input area so that users can easily specify whose opinion their comments are directed at and whether they are comments of approval or opposition. In addition, we modified it so that hashtags could be automatically applied based on these results, which facilitate statistical analysis such as word appearance frequency by category. Furthermore, the Twitter constraint of 140 characters or less, including hashtags, was expected to encourage users to express their opinions concisely because the such texts are automatically broken up into separate "tweets" when the 140-character limit is exceeded.

(3) We implemented a display area that is dedicated to Social-MRC, in the lower part of the screen, as shown in Fig. 7. Users can select and display various functions relating to Social-MRC from this area. For example, users can display the opinions of opinion leaders, or they can display the optimization results calculated in MRC-Studio for various scenarios, for mutual comparison purposes. There is also a function for selecting whose optimal solution is most desirable.

The program was implemented on the MRC-Plaza server using Java and JavaScript in a Windows 7 environment. The total number of coding steps was approximately 4,000. The program is described in detail in Ref. [12].

4.4 Experimental Application of Social-MRC

We experimentally applied the above Social-MRC program to the problem of information filtering for children, as detailed below.

(a) Opinion leaders (2 persons): Pro-regulation side (Professor A, role-playing as PTA chair)

Anti-regulation side (Professor B, role-playing as freelance journalist)

(b) Facilitator (1 person): Advances the discussion (Professor C)

(c) Director (1 person): Editing for MRC-Plaza server (student)

(d) Camera operator (1 person): Records the discussion (student)

(e) MRC specialist (1 person): Changes the values of the constraints, and calculates the optimal solution using MRC-Studio (student)

(f) Ordinary stakeholders (29 persons): Primarily science students. These persons watch and listen to the discussion, write opinions, fill out questionnaires, confirm the optimal solution from MRC-Studio, etc.

1. Objective function: Min {Risk to children + Total cost of measures} (in yen)
Example of risk to children: No. of annual suicides from viewing Websites
Amount of damages from suicides
2. Constraints:
(a) Risks to children
Events not desirable to children (number of victims such as suicides)
(b) Convenience burden
For guardians: Time and effort spent on judging whether to filter child's mobile phone (value from 0–1: relative value)
For Website managers: Time and effort needed for measures to prevent children from viewing damaging information (value from 0–1: relative value)
3. Number of proposed measures: 15 (specific proposed measures and formulation results are the same as for when the prototype program was applied, as described in detail in Ref. [13])
4. Experiment implementation time: Approximately 90 minutes

4.5 Main Application Results and Considerations

The main application results are as follows.

(1) The MRC specialist indicated the objective functions and constraint values under current laws, and the optimal solution for the pro-regulation side and anti-regulation side respectively. The opinion leaders then expressed their respective opinions. The process was broadcast on Ustream, after which ordinary stakeholders were asked for their opinions. There were 14 votes for the pro-regulation opinion leader and 15 votes for the anti-regulation opinion leader. Thus, the weight of support was for the anti-regulation opinion leader.

(2) Debate was carried out among the opinion leaders, based on the optimal solution from the opinion leader opposed to the regulation and taking into account opinions received from ordinary stakeholders via Twitter. Some opinions from those in favor of regulation were adopted and MRC-Studio was used to calculate a solution three times. The third solution became a tentative consensus solution.

(3) When the tentative consensus solution was presented to ordinary stakeholders to ask whether they supported it, there were 17 votes in favor and 12 votes against. This was taken to be a vote in favor of the tentative consensus solution, and since there were a majority of persons in favor, the meeting was brought to a close.

We elucidated the following points from these application results.

(1) The calculation of the optimal solution in MRC-Studio took approximately two minutes each time and was not a major constraint. The calculation time does not change even if the number of ordinary stakeholders increases, and so there are no constraints on applying the system for meetings with several thousand ordinary stakeholders.

(2) We developed the display shown to ordinary stakeholders in MRC-Plaza to appear as in Fig. 7. The screen shows the output results from MRC with Ustream and Twitter running simultaneously, fulfilling the basic features that we targeted. There was a time lag of around 10 seconds for the video broadcast, but this did not particularly hinder the operation. The video lag does not change even if the number of ordinary participants increases, and so it will not become a bottleneck for applying the system to problems with several thousand ordinary stakeholders. Accordingly, we confirmed that the basic features can be achieved.

(3) There are few Ustream broadcasts with more than 10,000 viewers. Even if the number of stakeholders increases, it should not be a bottleneck for up to 10,000 viewers. However, if the number of ordinary stakeholders increases to several thousand people, the number of people inputting comments from Twitter increases significantly, making it difficult for people to view and confirm the comments. This has been confirmed from observations of separate meetings that use Ustream and Twitter. Accordingly, we confirmed that application of the system for meetings with several thousand people requires a capability for (semi-)automatic analysis of inputs from Twitter, which we are currently developing

5. Conclusion

In this paper, we described the considerations that risk communication for IT systems should take. We then described the MRC that we developed for consensus formation within organizations, and confirmed the mechanism of the Social-MRC system that we developed to support social consensus formation as well as the results of applying the systems to various problems.

Through the application of these systems, we were able to confirm that both support systems were effective. Therefore, it can be said with confidence that our study, as described in this paper, has demonstrated a comprehensive approach to risk communication for IT systems for the first time in the world.

We plan to further develop the systems in the following ways:

(1) Increase the number of people who can use MRC and further apply the system to other cases. In order to accomplish this, we will continue to conduct MRC education in various settings. Furthermore, we are currently working on and will soon finish the development of the MRC-Lite [14] support system, which integrates semi-quantitative assessment methodologies for people who find it difficult to formulate optimization problems.

(2) Make Social-MRC easier to use. To accomplish this, we will integrate functions such as for (semi-)automatic analysis of inputs from Twitter.

(3) Conduct an experiment to apply Social-MRC to the issue of information filtering, for several thousand people. Afterward, we will apply Social-MRC to the issue of information filtering and other problems in practical ways.

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