Toward Delegated Democracy: Vote by Yourself, or Trust Your Network

Hiroshi Yamakawa, Michiko Yoshida, Motohiro Tsuchiya

***Abstract*—.** The recent development of Information and Communication Technology (ICT) enables new ways of "democratic" decision-making such as a page-ranking system, which estimates the importance of a web page based on indirect trust on that page shared by diverse group of unorganized individuals. These kinds of "democracy" have not been acclaimed yet in the world of real politics. On the other hand, a large amount of data about personal relations including trust, norms of reciprocity, and networks of civic engagement has been accumulated in a computer-readable form by computer systems (e.g., social networking systems). We can use these relations as a new type of social capital to construct a new democratic decision-making system based on a delegation network.

In this paper, we propose an effective decision-making support system, which is based on empowering someone's vote whom you trust. For this purpose, we propose two new techniques: the first is for estimating entire vote distribution from a small number of votes, and the second is for estimating active voter choice to promote voting using a delegation network. We show that these techniques could increase the voting ratio and credibility of the whole decision by agent-based simulations.

***Keywords*—** delegation, network centrality, social network, voting ratio.

I. Introduction

VOTING plays an important role in democratic systems. It is an effective means to reflect the majority's intention within a limited amount of time. However, it is also true that voting is not a perfect solution for making decisions.

The recent development of computer and communication technologies and the digitalization of information are producing new ways of "democratic" decision-making. For example, page-ranking systems by search engines and recommendation systems of online shopping sites use such "democratic" systems.

In the world of real politics, this kind of "democracy" has not been acclaimed yet. A voter still does not want to use a computerized system to recommend a candidate whose policy perfectly matches his/her preferences.

Decision-making by delegation networks in organizations depends on rich social capital. Social capital includes trust, norms of reciprocity, and networks of civic engagement [1].

Hiroshi Yamakawa is with Solution Technology Lab., FUJITSU LABORATORIES, 1-1, Kamikodanaka 4-chome, Nakahara-ku, Kawasaki, Kanagawa,211-8588, Japan, (e-mail: ymkw@jp.fujitsu.com)

Michiko Yoshida is with Economic Research Centre, FUJITSU Research Institute, 11th Fl. New Pier Takeshiba South Tower, 1-16-1 Kaigan, Minato-ku, Tokyo 105-0022, Japan (e-mail: michiko.yoshida@jp.fujitsu.com).

Motohiro Tsuchiya is with the Graduate School of Media and Governance, Keio University, 5322 Endo, Fujisawa-shi, Kanagawa, 252-8520, Japan (e-mail: taiyo@sfc.keio.ac.jp).

As the phenomenon known as Web 2.0 gathers attention, trends such as blogs (diaries) and social networking services (SNS), where individuals transmit information and share it on the internet, are becoming prominent. SNS can be thought of as one example of the utilization of delegation networks in organizations. In SNS, one can search for a key person who is knowledgeable in a certain field of study and entrust that expert with one's vote.

Minetaki and Yoshida indicate in the analysis of intranet social networking services that there exists rich social capital, and those employees have mutual consideration through consequences of communication. Even within a closed company environment, the visibility of communication chains among employees from various departments disseminating knowledge from different domains fosters a sense of shared trust [2].

In SNS, users can visit key persons' pages and find out what they say in their diaries, as well as their comments made on other diaries. We assume that key persons are those who have many networks of contacts (the number of "friends" in the SNS), comment on various employees' diaries, and write appropriate comments as occasion may demand. They are also unique persons whom many employees pay attention to. Other employees can visit these key persons' pages directly and it may enhance awareness for these employees. Social capital in social networking services enhances decision-making.

In this paper, we will propose a new way of decision-making with the help of a computerized system. It is not a fully computer-dependent voting system. It is a system to empower someone whom you trust, and to make the whole decision-making process more effective. Some people don't take time to vote, because they are not interested in current agendas or because they have different priorities. Even so, it is not ideal to make a decision with fewer people's votes. In our proposal, people give their votes to someone whom they trust and a computer system monitors what trusted voters do until the last minute of voting. This system could raise the voting ratio and credibility of the whole decision.

It is quite an unusual way in a democratic system to give a vote to someone else. It is obvious that such a system is against the principle of equality in voting where everyone has only one ballot. However, our system could minimize wasted votes, which should not be overlooked in a democratic system. In our system, people make the best use of their votes by trusting their networks, and they stop wasting their ballots.

II. OPINION COLLECTION AND CONSOLIDATION TECHNIQUES

In an ordinary decision-making process, voters vote on their opinions at the end of discussion. On the contrary, we assume a different decision-making process. In this process, opinion proposals and voting for them are simultaneously executed. Each voter can directly vote opinions and/or delegate to other voters, and can change these attitudes anytime during decision-making session.

A. *Total vote estimator (TVE) using a delegation network*

The delegation network is composed of each voter's declaration of delegating to other voters. Each voter can freely allocate the delegation rate to any other voters.

Transitivity is assumed on the delegation relations. In a word, "I partially trust someone who is trusted by any other person whom I trust." Recursive vote circulation is justified under this assumption. Each voter can participate in a decision-making not only by estimating opinion, but also by delegating to any other voters.

For calculating indirect vote to opinions, we propose the total vote estimator (TVE) technique by using a delegation network. Here, the delegation network is composed of N voters' node and M opinions' node. Edges between voters are a subset of NxN delegation. Edges from voters to opinions are a subset of NxM direct vote.

We introduce LxL delegation matrix which values W (= {wij). Each element wij represents delegation or vote from voter i to voter/opinion j. So sum of output from each voter is one. ($\sum_j w_{ij} = 1$). Because we think delegation certainty decreases through multiple delegation steps, we assume vote propagation decay by propagation rate r (0 < r ≦ 1).

Firstly, all elements of L rows flow vector $\mathbf{f}(t)$ are initialized to zero. ($\mathbf{f}(0) = (1,...,1)^T$). (t is iteration step). Vote propagating calculation process is repeated until convergence condition is satisfied. (Condition: $\max(f_i) < 0.0001$ or t>T, T is maximum iteration steps).

$$\mathbf{f}(t+1) = rW\mathbf{f}(t) \tag{1}$$

Indirect vote vector F is defined as an iteration sum of flow vectors.

$$\mathbf{F} = \sum_{t=0}^{T} \mathbf{f}(t) \tag{2}$$

The infinite iteration limit of this vector is proportional to eigenvector centrality (Bonacich's centrality). ($T \to \infty$). Because one vote was arranged in the initial value on every opinion, we obtain indirect vote value for opinions by subtracting one from vector F.

Under this mechanism, voters can freely delegate to any other voters; it means that any voter can receive delegation without direct vote to any opinions.

By setting the iteration limit T=1, we can easily obtain direct vote vector without delegation.

Network sampling is research field related to TVE technique [3, 4, 5]. For example, the number of drug addiction patients is estimated by using the friend network.

B. *Active voter choice (AVC) using a delegation network*

When members of an introvert group delegate to each other and none of them vote to opinions, the TVE can not estimate an appropriate indirect vote.

We therefore propose the active voter choice (AVC) technique which picks up powerful voters in a delegation network. The chairman can effectively grasp various voters' preferences by concentrating vote promotion on powerful voters. Here we propose the greedy voter sampling method as AVC. This sampling selects powerful voter sequentially, so as to maximize the total indirect vote.

Formally, the vote action of voter i to opinion is represented by the change of delegation matrix W. Firstly, voter i cancels delegation to other voters. Secondly, voter i votes to opinions according to preference vector **y**i. Here, preference vector yi represents the opinions preference of voter i.

Here, we call opinion voting voters subset s, and the indirect vote vector corresponding to s is F(s). Then the total indirect vote is $\Phi(s) = \sum_{c \in C} F_c(s)$. The variation of Φ by adding one voter, who does not vote to opinions yet, is described by the following expressions.

$$\Delta_i \Phi(s) = \Phi(s+i) - \Phi(s) = \sum_{c \in C} (F_c(s+i) - F_c(s)) \tag{3}$$

Here a new subset of votes including newly added voter i is described as s+i.

This sampling method greedily accumulates total indirect votes, so that a powerful voter i(s) suitable for vote promotion is selected by this expression.

$$\tilde{i}(s) = \arg\max_{i \notin s} \Delta_i \Phi(s) \tag{4}$$

If a voter who is promoted by this sampling method could really vote to opinions, total indirect votes will increase quickly and the chairman will grasp various voters' preferences effectively.

To evaluate the basic performance of the AVC technique, we assume that promoted voters always vote to opinions, and voters do not vote to opinions without promotions.

III. MODELING VOTERS AND DELEGATE NETWORK

A. *Model of voters*

We assume that opinions are allocated on the one dimension value spaces v (= [0, 1]).

The preference center of voter i is represented by vi. These vi are allocated in value space with a mixture of two beta distribution manners. $(2B(1.2,5.0)+B(5.0,1.2))/3$. As shown in figure 1, the largest faction stands at v=0.05 and the second faction stands at v=0.95. This distribution is preserved in all of the experiments in this paper.

There are ten opinions on values space (M=10), and these opinions are allocated in even intervals (vc = [0.05, 0.15,…, 0.95]). Opinion preference vector yi of each voter is specified by normal distribution around center value vi.

$$y_{ic} = \frac{\exp(\beta(v_c - v_i)^2)}{\sum_c \exp(\beta(v_c - v_i)^2)} \qquad (5)$$

Parameter β is set to 15.7, in experiments, and then the half band width in the value space is about 0.4.

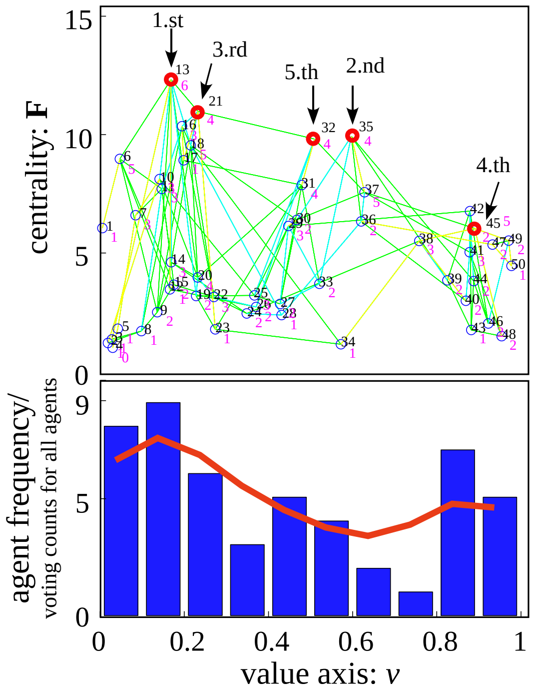

Figure 1. Example of delegation network in value space.

The 50 voters are arranged on the horizontal value axis. In the lower figure below, the blue histogram describes the distribution of voter's value center, and the red line describes all voters' voting sum. In the upper figure, the vertical axis is indirect votes, nodes are voters, and delegation relation is described by the link. For each node, ID is described by a black number and the degree of receiving delegation is described by a pink number. The first five selected voters are indicated by the red circle.

B. *Model of delegates networks*

In our acquaintance network model, when voter i knows the sense of values of voter j, there is an acquaintance relation. To generate a network, k voters are randomly selected among the N-1 voters as each voter’s acquaintance. These relations are asymmetric, so voter i does not always knows voter j while voter j knows voter i.

Each voter delegates to his acquaintance, so as to reproduce his sense of values as much as possible. Formally, each voter i selects delegation weights $\mathbf{w}_i (= \{w_{ij} \mid j \in K_i\})$ to minimize the error between self vote vector yi and a weighted linear total the vote vector of the acquaintance using quadratic programming. Here Ki is acquaintance set of voter i, and ε is small positive.

$$\underset{\mathbf{w}_i}{\text{minimize}} [[\mathbf{y}_i - \sum_{j \in K_i} w_{ij} \mathbf{y}_j]^2 + \varepsilon |\mathbf{w}_i|^2] \qquad (6)$$

Finally, wij is normalized $\sum_j w_{ij} = 1$. Thus, the delegation network is constructed from the acquaintance network.

The upper figure of Figure 2 shows one example of the composed delegation network. The vertical axis is a number of indirect votes, and the delegation relations between voters are described by links without distinguishing direction.

IV. SIMULATION RESULTS

We simulated 50 voters by using the voter model and the delegation network model. The number of direct votes and indirect votes are calculated for two kinds of voter choices. Here, propagation rate r=0.8.

Table 1. Four types of experimental setup.

Total vote estimation (TVE))		Indirect vote vector	Direct vote vector
Voter choice	AVC	**Avc-I**	**Avc-D**
	Random	**Rnd-I**	**Rnd-D**

For Avc-D, Avc-I, and Rnd-I setups, 100 kinds of delegation networks are generated and the result is averaged. For all setups, 100 kinds of delegation networks are generated and the result is averaged. For the Rnd-I setup, three different random voter choice sequences s are simulated and averaged in each delegate network anymore. For Rnd-D setup without delegate network, 1000 of different random voter choice sequences s are simulated and averaged.

A. *Evaluation of fairness and costs*

We simply assume that decision-making costs are the number of voting voters. For evaluating fairness, we introduce two measures. Firstly, we introduce total vote as a measure. $\Phi(s) = \sum_{c \in C} F_c(s)$ Secondly, we introduce essential distribution estimation ability (EDEA).

To evaluate the EDEA, we use the logarithm absolute error between the vote distribution with partial voters $F_c(s)$ and the vote distribution with all voters y_{ic}.

$$e(s) = \log \sum_c \left| \frac{F_c(s)}{\Phi(s)} - \frac{\sum_i y_{ic}}{N} \right| \qquad (7)$$

Maximum iteration step T must be large enough for an indirect vote vector F calculation on equation 2. On the other hand, T is set to 1 (T=1) for a direct vote vector calculation.

As a standard, logarithm absolute error e(s) using Rnd-D setup is averaged with 1000 voter sequences. EDEAs are logarithm absolute error e(s) normalized by former standard.

B. Result 1: Number of acquaintances k is ten (k=10)

An acquaintance network in which each voter has ten acquaintances is generated.

Basically voters are selected one by one from the voter who has a larger indirect vote by using the AVC. In this example, voter selecting sequence [13, 35, 21, 45, and 32] does not completely match the order of indirect vote value.

The phenomenon of order changing is derived from the following two mechanisms. For instance, a strong delegation relation exists from a voter i to a voter j. In the first case, if voter i voted choices directly, the indirect vote of voter j is decreasing. In the opposite case, when a voter i already votes to choice, voter j's vote action to choice is not contributed to enhance the total indirect vote.

So when there is a strong delegation relation between two voters, these two voters are not probably selected simultaneously. We assume that voters who have a similar sense of values have a delegate relation with each other. Therefore, voters who have mutually different values tend to be chosen.

Figure 2 shows an averaged total vote to the number of voting voters. By the Rnd-I (random voter choice & indirect vote) setup even 15 voting voters can collect 35 total votes. By the Avc-I (active voter choice & indirect vote) setup, 10 voting voters can collect 37 total votes, and even four voting voters can win a majority.

Next, effective EDEA (essential distribution estimation ability) for assessing the fairness against the number of voting voters are shown in Figure 3. Values of EDEA are also the average of hundreds of simulation trials. By the Rnd-I setup, 30 voting voters achieve EDEA by over 40 voters in Rnd-D setup. By the Acv-D setup, 10 voting voters achieve EDEA by over 25 voters in Rnd-D setup. In this setup, EDEA performance is unstable but it does not stand out because the graph curve is the average of 100 trials. By the Avc-I setup, 15 voting voters achieved EDEA by about 45 voters in Rnd-D setup, and even six voting voters can win a majority. In this setup, a total vote estimator technique stabilizes the EDEA performance.

C. Result 2: Changes of Number of acquaintances k (Avc-I)

For checking the EDEA performance against the change of network character, we compare the result of different numbers of acquaintance k. In Figure 4, we show the EDEA curve of the Avc-I (active voter choice & indirect vote) setup. In simulation, the numbers of acquaintance equal {1, 2, 3, 4, 5, 6, 7, 8, 10, 12, 15, 20, 30, and 40}.

By fewer voting voters, the higher the number of acquaintances are, and the higher the EDEA performances are. EDEA performances are apparently enhanced when each voter has more than five acquaintances. EDEA performances almost saturate when each voter has more than fifteen acquaintances. Because each voter delegates other voters who do not have similar senses of value, EDEA performance unexpectedly degrades when each voter has less than three acquaintances.

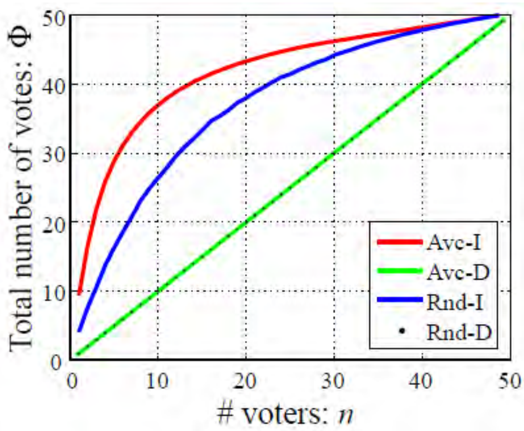

Figure 2. Relation between numbers of voting voters and total votes (Number of acquaintances: k=10)
Number of voters N=50. Propagation rates r= 0.80.

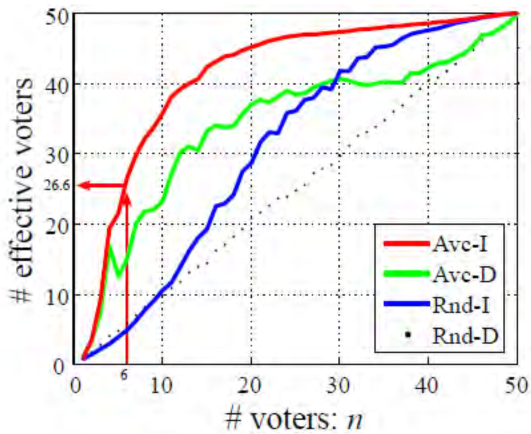

Figure 3. Relation between numbers of voting voters and effective EDEA (Number of acquaintances: k=10)
Number of voters N=50. Propagation rates r= 0.80.

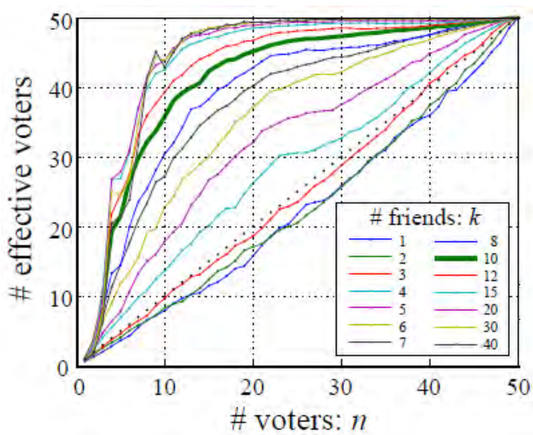

Figure 4. Relation between numbers of voting voters and effective EDEA for the different number of acquaintances. (Avc-I)
Number of voters N=50. Propagation rates r= 0.80.

V. Conclusion

We proposed two vote supporting techniques using a delegation network which is based on trust, norms of reciprocity, and networks of civic engagement. First, total vote estimator (TVE) technique estimates total vote distribution from a small number of votes by assuming transitivity relation on delegation network. Second, the active voter choice (AVC) technique picks up powerful voters who are suitable for to target for vote promotion in a delegation network.

To estimate the ability of these techniques, we simulated the decision-making process using an artificial multi-agent system. In this simulation, we assumed that 50 voters were arranged in a different position on a one-dimensional value space. Each voter had ten friends, knew their values and gave the commission of authority to some of them. The voter was selected one-by-one using the active voter choice method, and indirect vote number counting was used for evaluating voting distribution. Six voters using the proposed method could outperform the half voters, concerning capability for estimating entire poll results.

These simulations showed that the proposed methods one to grasp the entire vote distribution from a small number of powerful voters. Although voters' attitudes in real decision-making processes have some differences from this simulation, we believe this system could potentially increase the voting ratio and credibility since people delegate to someone they trust and monitoring each other by using this system.

References

[1] R. D. Putnam, *Making Democracy Work: Civic Traditions in Modern Italy*, Princeton: Princeton: Princeton University Press, 1993.

[2] K. Minetaki, and M. Yoshida, “Service Innovation Generated by Innovation in ICT --- Blogs/SNSs and Innovation ---The Effect of Blogs/SNSs as seen from a Survey of Employees,” *Fujitsu Research Institute Research Paper*, No. 282, 2006.

[3] K. Krippendorff, *Content Analysis: An Introduction to Its Methodology*, Sage Pubns, 1980.

[4] M. G. Sirken, “A Short History of Network Sampling,” in *Proc. SRMS*, 1998.

[5] S. K. Thompson, "Adaptive Web Sampling," *Biometrics*, vol.62, no.4, pp.1224--1234, 2006.

Hiroshi Yamakawa (Dr. Engineering)
Physical master's course of Department of Science at The University of Tokyo is completed in 1989. An electronic doctor's course of Department of Engineering at The University of Tokyo is completed in 1992. I joined Fujitsu Laboratories in 1992, and then I participate in the national projects sensor fusion.

After 1994 I joined the Real World Computing project till 2000. I am engaged in the researches on a neural net, reinforced study, the concept learning, and bioinformatics, etc.

Now I work for IT core laboratory, Fujitsu Laboratories ltd. I am member of the Institute of Electronics, Information and Communication Engineers, Japanese Cognitive Science Society, Japanese Neural Network Society, Japanese taste, smell academic society, Japan tennis society, and Artificial Intelligence Society.