Design concept of community currency based on fuzzy network analysis

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Abstract

This paper proposes a way to evaluate the ability of exchanging goods and/or services via community currencies by introducing a method to analyze the reciprocity of communities based on a fuzzy network analysis. These currencies are expected to reinforce various social communities that face difficulties due to the attenuation of human relation, and dramatically spread over to resolve these difficulties. Community currencies circulate in particular areas or communities and are expected to enhance social capitals. The significance of reciprocity in a community is discussed which is used to evaluate the community where the nonadditivity of the evaluation measures reflects the nonadditivity of relationships among community members and/or members' activities. That is, we use a fuzzy measure to analyze the reciprocity based on the fuzzy network analysis which provides us with a certain guideline for the emergence of interpersonal relationally among members in a community.

Keywords: Community currency, Reciprocity, Fuzzy network analysis, Fuzzy measure, Choquet integral

1. Introduction

Communities, that are not necessarily local, still have a great part in our daily mutual aid and social activities, and it is expected that our communities will play more important roles. Nevertheless these communities seem to decline recently because of the attenuation of human relations. Now community currencies become popular in the world for resolving this problem. We expect our community more livelily and harmonious by the use of these currencies. Thus we can anticipate that community currencies, different from national global currencies, reflect reciprocity to enhance community relationship through the mutual aid in social communities.

Using fuzzy logic, we will propose a novel evaluation method of reciprocity on community currency. In this analysis we will also make a proposal on the way of reflecting emergence of social capital through exchanging goods and/or services via community currencies among community members.

First, we will introduce the notion of community currency in concrete and actual forms and state its expectable properties; reciprocity. Next, we will introduce Fuzzy network analysis with which we evaluate reciprocity of communities. Then, we will propose evaluation method of reciprocity in a community using Fuzzy network analysis. Finally, we will think about the parameters, review the model and state the way how we can get guidelines for an emergence of hearted interpersonal relationships in a community.

2. Community currency

2.1 General perspectives on community currencies

A community currency is defined as a currency that circulates in a limited area or inside a social group. People use a community currency, as usual currencies, to exchange goods or services and to communicate with each other in a community whose members have trust in their community. Now, community currencies spread over for various purposes in the world (Lietaer, 1999). Generally speaking, there are three types of community currencies; one is used to promote local economy, another is to support for mutual aid, and the other is the hybrid of these two. In this paper, we will focus on the second, that is, the role of supporting for mutual aid.

2.2 Essence of community currencies

According to Niklas Luhmann a currency has bilateral character, called “symbolic” and “diabolic” characters of currency, each of which is used to link people or to separate people (Luhmann,1988). Moreover, it is impossible this bilateral character is separated. On the one hand,

N. Luhmann said, a currency is a media which is symbolically made though generalization. Symbolic generalization is to outreach differences on three dimensions: time, event and social. In fact, this means currency can be used whenever, for whatever and to whomever. Generally they are called basic functions of currency, i.e. , means of storing values, measure of value and medium of exchange. Therefore currency is considered as communication media providing opportunities to communicate with each other. On the other hand, the diabolic character of currency refers to the diabolic aspect of symbolic generalization. For instance, this diabolic character lead to financial crisis, supremacy of money and economic disparity, etc. N. Luhmann said that the most diabolic character is to attenuate reciprocity.

A community currency is partly limited on symbolic generalization to limit diabolic aspect and link people again. In other words, national currency is a communication media which looses reciprocity while a community currency is a communication media resuming reciprocity.

2.3 Reciprocity

In this paper, reciprocity is considered to be a general tendency on the mutual exchange in a community, a person will feel a demand for him/her and also will contribute to restoring balance in long time, even though all the members of the community may feel unbalance at each instant of time (Konma, 2000). A payment with national currencies will culminate exchange. Reciprocal exchange with community currency, on the contrary, will sustain exchange in community to balance. Furthermore, reciprocal exchanges may be considered as a gift.

We introduce “KuraRing” as a classical example of reciprocal exchange system. In the Trobriand Islanders, the southeast corner of Papua New Guinea, kularing is a unique and fascinating dealing system within the Trobriand society. This is a circular dealing system with two shell ornaments. A dealing involves an ornament moving clockwise through the island network, while another ornament moves counterclockwise. Thus, this dealing system is expected to form a huge circle linking. In the dealing system known as the “Kula Ring”, the objective of the dealing is not merely economical gain, but also reinforcement of interpersonal relationships.

2.4 Time dollar

In this subsection, we introduce Time dollar (http://www.timedollar.org/index.htm)as an example which reflects the reciprocity. Now the regions adopting this system have spread in the United States; there are than 200 projects. The original concept of time dollar purposed by Edgar S. Cahn in 1980 is as follows: People who are eager to join time dollar must register for the secretariat. The secretariat regularly publishes a journal by which people can get information on the variety of goods and services that can be offered or be demanded by the members. Then, a member may contact another member through the introduction by the secretariat (coordinator). The essential characteristic of time dollar is "pricing" on the unit of the currency, that is, "an hour". This means that whoever a person is and whatever service or good is, all is the same price that is an hour. In fact people may feel unbalance of dealing each time, but time dollar focuses on balance of dealing in the long time. Moreover, it is remarkable that time dollar cannot be changed with national currency and is free of interest (being without interest, that is, zero interest rate). Hence, there is no duty of repayment, because the purpose of time dollar is to support the gift; it has no meaning to save time dollar. This system indicates that time dollar is based on the trust among the members and is quite different from the national currencies which we are accustomed to. Now we come to think that people who join time dollar will be interested in not only receiving benefit or convenience but also contributing to their community and to help each other.

In the next subsection, we will introduce the notion of social capital that is the final objective of time dollar by to E. S. Cahn. It will provide us with several points of view on that we must take account when we think about the roles of the reciprocity in a community.

2.5 Social capital

The notion of social capital provide us with a useful way of entering into debates about civil society. Social capital expresses three basic features on social life: social networks, the norms of reciprocity and trustworthiness, all of which enable us to collaborate efficiently with community in order to pursue our common purpose (Putnam, 2000). It is significant property of social capital that three features affect each other as shown Fig. 1. If these strengthen then a community revitalize in a virtuous circle, similarly if these weaken then a community declines in a vicious circle. Thus when trustworthiness weaken in community, it is difficult to strengthen trustworthiness from the beginning but it is possible to strengthen social networks and the norms of reciprocity. Therefore, it is possible to find the validity of a community currency from this point of view.

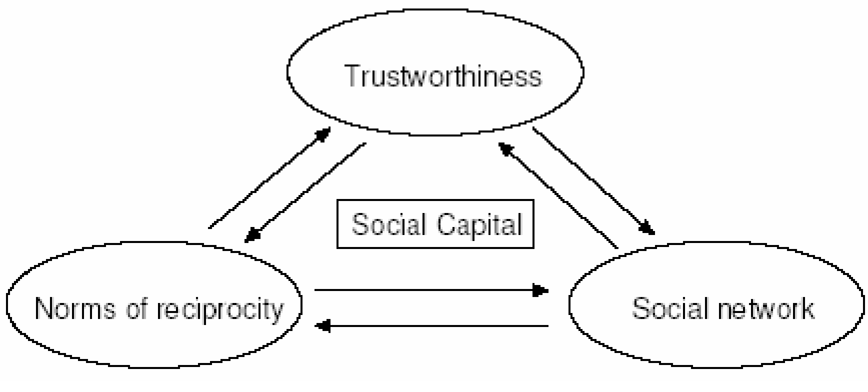

Figure 1. Concept of Social Capital.

On the analysis of social capital in real societies, W. Baker and J. Kanamitsu evaluated social capital based on network analysis (Baker, 2003) (Kanamitsu, 2003). They disregarded the reciprocity in a community, their researches did not treat the social capital that R. D. Putnam had examined. Therefore, we propose an evaluation method of reciprocity based on Fuzzy network analysis.

3. Fuzzy network analysis

3.1 Fuzzy graph

For the network analysis, we often uses graph theory, even though two valued logic is not enough to address various problems in the real society. Thus the notion of fuzzy graph is expected to be suitable at to deal many valuedness of the real society and to carry out mathematical analysis easily (ka *et al.* ,1995).

3.1.1 Def. of Fuzzy power set

Let U be an universal set. If there is a set s.t.

$$F(U) = \{\tilde{A} | \mu_A : U \to [0,1]\}, \tag{1}$$

then F is called a fuzzy power set.

3.1.2 Def. of Fuzzy graph

Let N be a finite set, $\tilde{N}$ be a fuzzy set s.t. $\tilde{N} \in F(N)$, and $\tilde{L}$ be a fuzzy set s.t. $\tilde{L} \in F(N \times N)$ for $\forall xi, \forall xj \in N$. If the following holds:

$$\tilde{L}(x_i, x_j) \le \tilde{N}(x_i) \wedge \tilde{N}(x_j) \;\; for \; \forall x_i, \forall x_j \in N, \tag{2}$$

then $G = \tilde{N}, \tilde{L}$ is said to be a fuzzy graph $\tilde{G}$. Furthermore connections between the node i and node j in the fuzzy graph need to be defined as the following holds:

$$r_{ij} : \begin{cases} 0 < r_{i,j} \le 1, & \text{if node } i \text{ and node } j \text{ are connected} \\ \quad r_{i,j} = 0, & \text{if node } i \text{ and node } j \text{ are disconnected .} \end{cases} \tag{3}$$

The relation of connection in the fuzzy graph is considered to be a fuzzy relation over N. Let the cardinal number of N be n. Then the relation of connection is given as the fuzzy matrix:

$$R = (rij)_{n \times n}, \tag{4}$$

where R is called the “fuzzy adjacency matrix”. It should be noted that any fuzzy adjacency matrix R is reflexive, that is, $R \supseteq I$.

3.2 Fuzzy transitive closure

The transitive closure of a directed graph represents the reachability in a network.

3.2.1 Def. of Fuzzy transitive closure

The fuzzy transitive closure of fuzzy adjacency matrix R is given as:

$$\hat{R} = R^n, \tag{5}$$

where R^n is the n times composition of R. The composition of relations $R = (r_{ij})_{m \times l}$ and $Q = (q_{jk})_{m \times l}$ is given as following:

$$R \times Q = S = (s_{ij})_{n \times k} = \left(\sup_{j=1}^{m} (r_{I,j} \wedge r_{j,k}) \right)_{n \times k,} \tag{6}$$

where $0 \leq I \leq 1$ and $0 \leq k \leq 1$.

3.3 αcut

3.3.1 Def. of αcut

Let $\tilde{A} bea\,f uzzysetand\alpha \in [0, 1]$. Then the crisp set given as:

$$(\tilde{A})\alpha = \{ u\ \mu_{\tilde{A}}\ (u) > \alpha,\ u \in U \}, \tag{7}$$

is called the (strong) αcut of fuzzy set $\tilde{A}$. Similarly, let R be a fuzzy adjacency matrix. If there is the matrix given as:

$$(R)_\alpha = \begin{cases} 1 & \text{if } r_{ij} > \alpha \\ 0 & \text{if } r_{ij} \leq \alpha \end{cases} \quad , \forall x_i, \forall x_j \in N, \alpha \in [0, 1], \tag{8}$$

is called the αcut of fuzzy adjacency matrix R.

3.4 Fuzzy measure

3.4.1 Def. of Fuzzy measure

Let $(X, \mathscr{F})$ be a measurable space. If $\mu : \mathscr{F} \to [0, \infty]$ is defined as:

$$\mu(\emptyset) = 0, \tag{9}$$

$$A, B \in \mathscr{F}, A \subset B \Rightarrow \mu(A) \leq \mu(B), \tag{10}$$

then μ is called a Fuzzy measure over $\mathscr{F}$. Here, the triple $(X, \mathscr{F}, \mu)$ is called “Fuzzy measure space”. Usual measures such as probability measures are kinds of specialized fuzzy measures satisfying the following “additivity of measures”:

$$A \cap B = 0 / \Rightarrow \mu(A \cup B) = \mu(A) + \mu(B) \tag{11}$$

In general, fuzzy measures do not presume the above additivity.

Due to the lack of the above additivity, we will have the following three cases with which the corresponding interpretations on the underlying social structures are associated:

$$\text{case1. } \mu(A \cup B) > \mu(A) + \mu(B). \tag{12}$$

There exists a positive (enhancing) synergy effect between events (or groups) A and B.

$$\text{case2. } \mu(A \cup B) < \mu(A) + \mu(B). \tag{13}$$

There is a negative (inhibitory) synergy effect between A and B.

$$\text{case3. } \mu(A \cup B) = \mu(A) + \mu(B). \tag{14}$$

Events (or group) A and B are independent of each other.

Thus fuzzy measures can naturally reflect the effects of internal interactions inside groups or systems via their essential characteristics, that is, the nonadditivity of measures.

3.5 Choquet integral

We will briefly introduce this novel notion of integral, Choquet integral, defined over non additive measures (Grabich *et al.* , 2000).

3.5.1 Def. of Choquet integral for the following stepwise function:

$$f(x) = \sum_{I=1}^{n} r_I 1_{D_I}(x) \quad . \tag{15}$$

where $r_0 = 0 < r_1 < r_2 << r_n$ and $D_I \cap D_j = \emptyset$ for $I \neq j$, the Choquet integral of f w.r.t. μ is defined as follows:

$$(C)\int f d\mu \doteq \sum_{I=1}^{n} (r_I - r_{i-1}) \mu(A_i) \quad . \tag{16}$$

For example, when n =4, stepwise function is written as follows (cf. Fig. 2):

$$f(x) = \sum_{i=1}^{4} r_i 1_{D_i}(x) = \sum_{i=1}^{4} (r_i - r_{i-1}) 1_{A_i}(x) \tag{17}$$

Thus, Choquet integral of f w.r.t. μ is represented as follows (cf. Fig. 3):

$$\begin{aligned} (C)\int f d\mu &= I + II + III + IV, \\ I &= (r_1 - r_0) \cdot \mu(A_1), \\ II &= (r_2 - r_1) \cdot \mu(A_2), \\ III &= (r_3 - r_2) \cdot \mu(A_3), \\ IV &= (r_4 - r_3) \cdot \mu(A_4). \end{aligned} \tag{18}$$

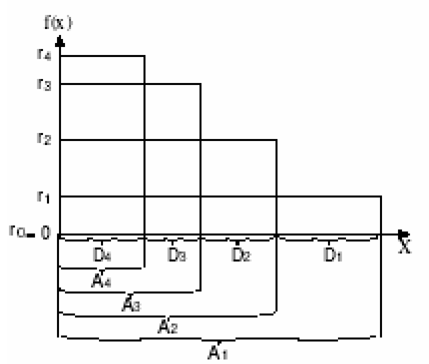

Figure 2. A stepwise function to be integrated with value ri in domain Di for I = 1, 2, 3, 4.

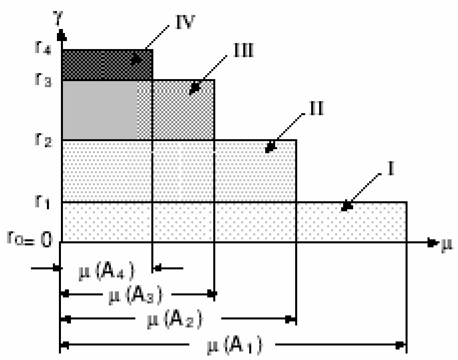

Figure 3. The choquet integral of the stepwise function as the summation of the horizontal columns I, II, III and IV.

4. Analysis of reciprocity

In this section we propose a novel evaluation framework to deal with a community currency in a community. Focusing on the reciprocity in a community, a flow of goods or services is important. This is because the reciprocity is inseparable from the phrenic load of others' gifts for three obligations: gifting, receiving and repaying (Mauss, 1954). We consider that the reciprocity will be higher as the balance of the flow can nicely be kept. Therefore, the reciprocity in the group is not the summation of individual dealing because of the nonadditivity of the measure on groups.

First, we draw a fuzzy graph of a community. A fuzzy adjacency matrix is obtained by an inverted flow of the community currency. This is because the exchanges imply not an dealing of goods and service such as in legitimate currency but a gift. For instance, participants of time dollar are more interested in contributions to others than to be given (Boyle, 1999). For example, we think about the case shown in Fig. 4. Each arc is associated with a numeral reflecting the dealing history, and each member in a community is represented as a node shown by symbols *a*, *b*, *c* and so on. Eq. 19 indicates R of the network in Fig. 4, and Eq. 20 indicates $\hat{R}$.

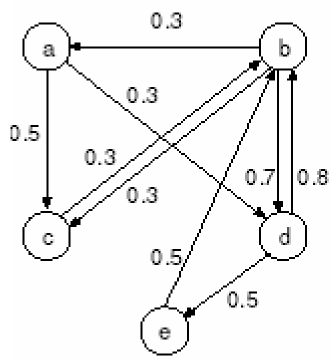

Figure 4. *A graphical representation of fuzzy relations.*

$$R = \begin{pmatrix} 1 & 0 & 0.5 & 0.3 & 0 \\ 0.3 & 1 & 0.1 & 0.7 & 0 \\ 0 & 0.3 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0.5 \\ 0 & 0.5 & 0 & 0 & 1 \end{pmatrix} \tag{19}$$

$$\hat{R} = \begin{pmatrix} 1 & 0.3 & 0.5 & 0.3 & 0.3 \\ 0.3 & 1 & 0.3 & 0.7 & 0.5 \\ 0.3 & 0.3 & 1 & 0.3 & 0.3 \\ 0.3 & 0.8 & 0.3 & 1 & 0.5 \\ 0.3 & 0.5 & 0.3 & 0.5 & 1 \end{pmatrix} \quad (20)$$

Next, let us consider the levels of reciprocity. This is because the reciprocity changes the property of the reciprocity according to the social distance on community (Sahlins, 1972). For instance, a low level of reciprocity takes the form of greetings, while a high level reciprocity takes the form of actions for local revitalization. So as to notice the level of reciprocity, we use the αcut operation to extract a fuzzy network by the αcut level. Hence, we call the αcut level

f : the level of reciprocity. For example, if f is 0.3, then we have

$$(\hat{R})_{0.3} = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 1 & 1 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 1 & 0 & 1 & 1 \\ 0 & 0 & 0 & 1 & 1 \end{pmatrix} \quad (21)$$

Likewise, if f is 0.3, then we have

$$(\hat{R})_{0.5} = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 1 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{pmatrix} \quad (22)$$

Then we will evaluate the reciprocity. We consider reciprocity as a balance of phrenic load of others' gifts, therefore we take notice of two measures, "integration" and "radiality". Integration measure and radiality measure indicate the degree an individual is connected and the degree of reachability within a network, respectively. The integration measure is based on inward ties, and the radiality measure is based on outward ties (Valente *et al.* , 1998). We consider the integration measure as the degree of benefits from a community and the radiality measure as the degree of contributions to community.

4.1 Def. of Integration measure

Let D be a distance matrix, n be the number of nodes. Then, the integration measure is defined as:

$$I(j) = \frac{\sum_{i \neq j} RD_{ij}}{n-1}, \quad (23)$$

where $I(j)$is the integration score for node j and RD_{ij} is called a reverse distance which is given as the following:

$$RD_{ij} = diameter - d_{ij} + 1, \quad (24)$$

where the diameter is given as the maximum value within the distance matrix. The lower value a distance is, the higher value a reverse distance has.

4.2 Def. of Radiality measure

Similarly, the radiality measure is defined as:

$$R(j) = \frac{\sum_{i \neq j} RD_{ji}}{n-1}. \tag{25}$$

We propose the measure on reciprocity measure on a fuzzy network based on integration the measure and the rediality measure. For this purpose, the reverse distance in a fuzzy network with αcut by *f* is defined as:

$$RD_{ij} = \hat{R}_{ij} \wedge \left(\hat{R}_{ij}\right)_f. \tag{26}$$

4.3 Def. of Reciprocity measure

The reciprocity measure of an individual in a fuzzy network with αcut by *f* is defined as:

$$\mu_{(individual)}\left(j_f\right) = \frac{I(j)+R(j)}{(1+|I(j)-R(j)|)}. \tag{27}$$

The reciprocity score will be high when both the integration and the rediality measures are high and the difference between them is small. Beside this, the integration measure for the network with αcut by *f* is operationally defined as:

$$\mu\left(R_f\right) = \frac{1}{n}\sum_k \frac{I(j)+R(j)}{(1+|I(j)-R(j)|)}. \tag{28}$$

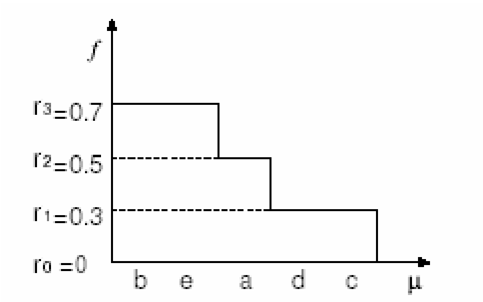

Figure 5. Reciprocity in a group evaluated by Choquet Integral.

This value represents the degree of the network, that is, being reciprocally connected. The reciprocity is represented as the sum of rectangular block described in Fig. 5.

$$Reciprocity\ of\ R = (C)\int f d\mu = \sum_{i=1}^{n} (r_i - r_{i-1})\,\mu\left(R_i\right). \tag{29}$$

The reciprocity of the group in a fuzzy network with αcut by f is given as follows:

Reciprocity o f R $= 0.3 \cdot \mu(R_0) + (0.5-0.3)\cdot \mu(R_{0.3}) + (0.7-0.5)\cdot \mu(R_{0.5})$

$= 0.3 \times 0.789 + 0.2 \times 0.416 + 0.2 \times 0.186$

$= 0.357.$ (30)

5. Discussion and Conclusion

In this paper, we have introduced community currency for constructing lively communities and taken account of the reciprocity that can be expected by the use of community currencies. The reciprocity contributes to emerge and accumulate social capital. Thus we have proposed an evaluation method on reciprocity using the fuzzy network analysis of social community. It should be noted that we can calculate the parameters in this analysis even though the nonadditive nature of the evaluation measure. Nonadditivity of evaluation measures reflects nonadditive relationships among community members or members' activities. Furthermore, the secretariat of the community currency can obtain useful suggestions form this evaluation method. For example, in the case of Fig. 4, it can be readily seen that person *b* should provide more service or goods for person *a* rather than for person *c* in order to construct lively community. This is because the dealing from person *b* to person *a* increases the measure by 0.2, resulting the reciprocity of community as 0.383, while the dealing from person *b* to person *c* increases the same, resulting the reciprocity of community as 0.371. Using this information, the secretariat can promote dealing with community currency effectively. The secretariat of community should not just wait for the outcome of the community currency, but should promote circulation of the community currency. This is because we think the emergence of social capital need to be moderately controlled.

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