Master Thesis

Designing a Profit Sharing Method able to Create a Variety of Services

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Abstract

Many people produce services and contents on the Internet. Those who just used services and contents in the past started to make them. It is necessary but is lacking to combine the preference of creators with the demand of users appropriately for the continuous development of these kinds of movement.

Creators can presume users' demand if the demand is expressed as money. The creators don't make various services or contents and just make them with much profit on assumption that they are selfish and can freely choose services or contents which they will make, so social surplus decrease because they won't make various services. It is called dilemma.

If creators cooperate to make an allocation by which all services are made (formation of total coalition), a variety of services are made and social surplus increases. If profit is divided equally, a creator who is dissatisfied exists because service that creators make and costs to make services are different. The discontent creator may withdraw from the total coalition. By application of Shapley value, we aim to decline complaint.

Shapley value is the way to distribute profit in a game in coalitional form with transferable utility and satisfies some desirable properties required from distribution of profit. This game is a game in which players make a group (coalition) to act in union and each group have profit which is determined by characteristic function. If characteristic function is super-additive, total profit becomes maximum value by formation of total coalition, it is expected that creators form total coalition and a variety of services is made.

This research tries to use methods sharing profit as situation demands, so challenges following issues.

Scope of Applying Shapley Value Applying Shapley Value does not necessarily increase utility of creators and social surplus. It is necessary to research conditions under which application of Shapley value surely produces a variety of services and increases utility of creators and social surplus.

Designing a Method to Share Profit and to Make a Group It is necessary to research an appropriate way to share profit for each creator and to decide the group which a creator belongs to.

We calculate cosine similarity of costs to make services of each creator as similarity between creators. That similarity between creators is low means that difference of costs of the creators is big and it is likelihood that preference of them about services to make is different.

If creators are dissimilar, they produce various services in a case of distribution based on creators' free will. Distributions of income by Shapley value cause unnecessary transfer of profit. So, competent creators who transfer their profit drop out of the way of Shapley value. We have to compare and study the case based on free will and the case based on Shapley value.

Firstly, this research tackles appropriate application of Shapley value by investing creators' actions (what service they will make), their utility, social surplus and so on by doing simulations.

Secondly, this research grapple with what method is necessary to make services based on outcomes of discussions and data by simulations. We design a method to produce a variety of services.

This research tries to use methods sharing profit as situation demands and achieved the following contributions.

Scope of Applying Shapley Value This research showed changes of creators' utility and social surplus as similarity between creators change. If the number of creators is two and they are dissimilar, the profit of competent creators in the case that distribution is based on creators' free will outweighs their profit in the case based on Shapley value.

Designing a Method to Share Profit and to Make a Group In the case that similar creators make a group and in the case that more than three creators make a group even if similar creators can not take part in same group by considering their creation career or something else, they can make a variety of services and increase social surplus by application of Shapley value.

多様なサービス創出を可能とする収益分配法の設計

宮浦 宏暢

内容梗概

インターネット上において，多数の人々が多様なサービスやコンテンツを作成するようになってきている．これらが継続的な発展を行うためには，サービスやコンテンツ作成者の選好と利用者の需要を適切に結びつけることが必要となる．複数の作成者間でそれらのサービスやコンテンツの作成をどのように分担するのかを決定するのは難しいが，これらの協創に関する支援は十分でない．

利用者の需要を金銭によって表せるとすれば，作成者はサービスやコンテンツに対する需要を推測できるが，収益性の高いサービスやコンテンツの作成に作成者が集中してしまう．多様なサービスやコンテンツが作成されない可能性があり，社会的余剰が減少するジレンマの状況に陥ってしまう．

多様なサービスが創出され社会的余剰を増加させるためには，作成者が協力してサービスの作成分担を割り振り作成可能なサービスが全て作成される様に分担を割り当てればよい（全体提携の形成）．作成したサービスから得られる収入を等配分すると，作成するサービスの違いや作成にかかる費用は違うので不満を持つ作成者がいる．不満を持つ作成者は全体提携の形成に協力しない．シャープレイ値を用い収入を分配することにより，作成者が持つ不満を少なくすることを目指す．

シャープレイ値とは，譲渡可能な効用を持つ提携形ゲームにおいて，得られる収入の配分を求める方法であり，配分に必要な幾つかの望ましい性質を満たす．提携形ゲームとは，あるゲームにおいて，複数のプレイヤーが共同行動をとるために集合（提携）を形成し，各提携に対する収入を特性関数により定義してあるゲームである．特性関数が優加法的ならば，全体提携を形成した場合に総収入が最も大きくなることが保証されるので，作成者達が全体提携を形成することが期待できる．

本研究では，利益分配方法の使い分けを目的とし，以下の問題に取り組んだ．

シャープレイ値の適用可能性　シャープレイ値を適用すれば全ての場合において作成者の効用や社会的余剰が高くなるとは限らない．どのような条件下ならばシャープレイ値を適用することによって，作成者の効用や社会的余剰を増加させ多様なサービスを創出できるかを明らかにする必要がある．

利益分配・グループ作成支援方法の設計　多数の作成者と多数の利用者からの要望を適切に結びつけるために，あるグループにはどの方法による利益分配が良いのかを決定したり，どのような作成者のグループを形成すれば良いのかを知る必要がある．

作成者間の類似度として作成者の作成費用のコサイン類似度を用いる．類似度が低いということは作成費用の差が大きいということになり，作成者が作成したいサービスの選好が異なる可能性が大きい．

類似度が低い場合，自由意思に基づく方法でも多様なサービスが創出され，作成者の効用も大きいと予想される．この場合，シャープレイ値を使って利益を分配すると，有能な作成者が不必要な収入の譲渡を行わなくてはならないので，シャープレイ値を用いる方法から離脱するかもしれない．このため，自由意思の場合とシャープレイ値の場合を比較・検討する必要がある．

自由意思に基づいた場合とシャープレイ値に基づいた場合と得られる収入を等配分した場合のシミュレーションを行い，作成者間の類似度と作成者の効用や社会的余剰の関係を調べる．

実際にどのような手法を利用すれば作成者の効用や社会的余剰を増加させることができるかを検討し，利益分配・グループ作成支援方法の設計を行う．

本研究では，利益分配方法の使い分けを目的とし，以下の貢献を達成した．

シャープレイ値の適用可能性　シミュレーションを行うことにより，類似度の変化による作成者の効用や社会的余剰の変化を明らかにした．作成者が 2 人の場合でかつ類似度が低い場合は自由意思による方法の方が有能な作成者の利得が大きいので，シャープレイ値による方法を適用できないことが分かった．

利益分配・グループ作成支援方法の設計　作成者数とサービス数が 3 以上の場合はシャープレイ値が適用できる．作成者数とサービス数が 2 の場合，過去の作成履歴等を参考に類似度の高い作成者同士をグループにするか，作成者を増やし 3 人以上のグループで作成するサービスの分担を決定することによりシャープレイ値による方法が適用できるようになり，社会的余剰の増加と多様なサービスの創出を図ることができる．

Designing a Profit Sharing Method able to Create a Variety of Services

Contents

Chapter 1 Introduction

Today, many people produce services and contents on the Internet. Those who didn't make new services and contents in the past started to take part in producing them by appearance of the way to easily make composite Web services called Mash up and the way to make with ease contents whose example is the Wikipedia on the Internet. It is necessary to combine the preference of creators and contents with the demand of users appropriately for the continuous development of these kinds of movement.

Mash up and Wikipedia lower the barriers of technical knowledge which is necessary to make composite Web services and contents and help more and more people to participate in making them. Therefore those who just used services and contents in the past started to make them. Communities between these creators and users come into being.

However, supports for these collaborations are lacking. Creators have difficulty in getting information about users' requirements for services and contents. Even if they know it, they find it difficult to decide how they share work to make services and contents because there are many requirements and many creators. Currently, creators make services and contents which they think interesting or useful. Though they can use bulletin boards in which they can share information, it is not enough and difficult to understand requirements and to decide how they share the tasks to make services or contents.

This research support operators of systems which help creators to get information of users ' requirements (or the services which users want). Now some operators administer the systems [1] in which users can satisfy their requirements that are getting answers of his/her question by paying money. Like this example, it is thought that there will appear the systems in which users can satisfy their requirements that are getting a web service which has the function he/she want (or users have creators make the service) by paying money.

In the website [2] which support developments of Mush Up, there are some

[1] i.e. Yahoo! Answers (`http://answers.yahoo.com/`)

[2] つくるぶ (`http://www.tkrb.jp/`)

cases that one comes up with an idea of a service and that another makes it for free. Now, there is no payment for the creator. Hence it is assumable that a creator makes the service with a function which one requires and for which he/she shows payment.

Creators can presume users' demand for services or contents if the demand is expressed as money. Creators don't make a variety of services or contents and just make them with much profit if creators are selfish and creators can freely choose services or contents which they will make. If creators selfishly decide the services which they will make, social surplus decrease because creators don't make various services. It is called dilemma. We are trying to avoid this situation and to increase utility of creators and social surplus by deciding the services to make by considering how to share profit according to Shapley value, not creators' own will.

Shapley value is the way to decide how players share profits in a game in coalitional form with transferable utility. A game in coalitional form is a game in which players make a group (coalition) to act in union and each group have profit which is determined according to characteristic function cfv . Transferable utility is a kind of utility which enables us to increase the utility of player B by decreasing the utility of player A by same amount. Money is an example of it.

All creators can cooperate and can share tasks to make services to get the maximum profit by sharing profit according to Shapley value. This enables creators to make a variety of services without overlap of choice of making services like when we admit free choice by creators' own will. Social surplus and creators' utility can also increase.

This research tries to use methods sharing profit as situation demands, so challenges following issues.

Scope of Applying Shapley Value Applying Shapley Value does not necessarily increase utility of creators and social surplus. It is necessary to research conditions under which application of Shapley value surely produces a variety of services and increases utility of creators and social surplus.

Designing a Method to Share Profit and to Make a Group It is necessary to research an appropriate way to share profit for each creator and to decide the group which a creator belongs to.

In order to share profit according to Shapley value, we have to define super additive characteristic function cfv, the value of which is an income of a coalition of creators. This research defines the cfv according to income from services which creators presume common information and according to the services which a creator can make. We can decide how to share income according to Shapley value by transforming from a problem to share income of services into a game in coalitional form with transferable utility.

We calculate cosine similarity of costs to make services of each creator as similarity between creators. That similarity between creators is low means that difference of costs of the creators is big and it is likelihood that preference of them about services to make is different.

If creators are dissimilar, they produce a variety of services and get high utility in a chase that we use creators' free will to decide what service creators will make. Distributions of income according to Shapley value cause unnecessary transfer of profit. It cause drop out of discontent creators who transfer their profit by accepting the way to use Shapley value without necessity. Therefore, we have to compare and study the case based on free will and the case based on Shapley value.

Firstly, this research tackles appropriate application of Shapley value by investing creators' behavior (what service they will make), their utility, social surplus and so on by doing simulations.

Secondly, this research grapple with what method is necessary to make services based on outcomes of discussions and data by simulations. We design the method to produce a variety of services.

Following is a structure of this paper. Chapter 2 is an introduction of existing related works. We describe relations and difference from this research. Chapter 3 is about formulation of issues about distribution of profit of services and its example. Chapter 4 is about the way to decide the choice of services by creators' own will by selfish creators and its problem. Chapter 5 is about the way to apply Shapley value for distributing profit and its advantages and problem. Chapter 6 runs a simulation about variable services and creators and makes sure in which case application of Shapley value is appropriate. Chapter 7 explains the method to support creation of a variety of services by distributing profit according to Shapley value. Chapter 8 shows a conclusion.

Chapter 2 Related Works

This chapter introduces methods to share profit in a game in coalitional form with transferable utility as a related work[1, 2] and discusses differences from this research.

2.1 Game in Coalitional Form with Transferable Utility

A game in coalitional form with transferable utility is shown in the following expression (1).

$$(C, cfv) \tag{1}$$

$C = \{c_1, c_2, c_3, \cdots, c_n\}$ is a set of players. Nonempty subset $S \subset C$ is defined as a coalition of players.

Function cfv corresponds to total profit $cfv(S)$ which is the members of given coalition $S \subset C$ get. Function cfv is a characteristic function of a game.Characteristic function of a game describes not only difference of physical and technical conditions, but also difference of social systems which define the game.

Basic property of characteristic function cfv in a game in coalitional form is super-additivity. That Characteristic function cfv is super-additive means equivalent to the following expression (2) for given coalition S and given coalition T which doesn't have intersection with each other. (2) indicates that to consolidate cooperation S and T and form much bigger coalition $S \cup T$ increases total profit of players more than to dissever S and T.

$$cfv(S \cup T) \geq cfv(S) + cfv(T) \tag{2}$$

If characteristic function cfv is super-additive, it is likely that players can get the max total profit by making total coalition. To make total coalition is to establish coalition which all players in set C join in a game in coalitional form with transferable utility (C, cfv). Shapley value is the way to distribute total profit which total coalition obtains.

2.2 Core

There is a concept called core about distribution of profit. Core is a set of the distribution in which no coalition opposes the distribution of profit.

If all coalitions satisfy (3), it is called that x satisfies coalitional rationality. Set of distributions which satisfy coalitional rationality is called core.

$$\sum_{i \in S} x_i \geq v(S), \forall a S \subset C \tag{3}$$

In the distribution of profit which belongs to core, total profit of all members in arbitrary set S outweighs total profit which set S can obtain. In this sense, no member of set S has dissatisfaction toward distribution.

It is easy to define core and its meaning is clear. Though there might be the case that each player 's degree of contribution is not taken into consideration in core, it is always taken into consideration in Shalpey value. Core has the problems that it becomes a huge area and it is difficult to find the most appropriate distribution and that it does not always exist.

A combination of two members from two different groups is called matching. Marriage Problem is the problem to make matching from two groups of men and women based on their order of preference. Gale and Shapley showed an algorithm to make stable matching which belongs to core in Marriage Problem and proved that core in Marriage Problem is not null [3]. Game model of Marriage Problem is used to the problem of employment of interns in hospitals, analysis of the labor market, and personnel distribution in an organization.

2.3 Nucleolus

Nucleolus [4] is the reasonable way to distribute profit under the sweeter condition than coalitional rationality. The concept of nucleolus is to compare which distribution is desirable in terms of distributive justice when two distributions x and y are given. The comparisons between distributions are based on excess of all realizable coalitions.

When distribution of profit $x = (x_1, \ldots, x_n)$ and coalition S are given, (4) is called excess of S in distribution x.

$$v(S) - \sum_{i \in S} x_i \tag{4}$$

The distribution with the smaller excess of the two distributions is defined as more acceptable. It is assumption that x and y are distributions. The smaller excess of the two biggest excess of x and y(the biggest excess in all coalitions ' excesses) is more acceptable. If the biggest excesses are same, it compares the second biggest excesses. If all excesses of the biggest excesses to kth biggest excesses are same, it compares (k+1)th biggest excesses and defines the coalition with the smaller excess of them as more acceptable. The distribution with no more acceptable distribution is defined as nucleolus.

2.4 Shapley Value

The following is the definition and characteristics of Shapley value and relationships between Shapley value and this research. Shapley value is one kind of values of game in a game in coalitional form with transferable utility. A game in coalition is a game in which players make a group to act in union. Transferable utility is one kind of utility which is possible to increase the utility of player B by decreasing the utility of player A by same amount. Money is an example. Coalition is a group composed of players to act in cooperation. Values of game are the evaluations that players themselves estimate before a game starts.

If characteristic function cfv is super-additive, the degree of contribution ϕ_i of player c_i is indicated by expression (5) and (6) by using Shapley value. This degree of contribution ϕ_i certainly satisfies total rationality.

$$\phi_i(cfv) = \sum_{c_i \in S \subset C} \gamma(S)[cfv(S) - cfv(S - \{c_i\})] \tag{5}$$

$$\gamma(S) = \frac{(|S| - 1)!(|C| - |S|)!}{|C|!} \tag{6}$$

$|S|$ is the number of members of subset S. $|C|$ is the number of members of set C.

Shapley value satisfies total rationality, zero evaluation of null players, symmetry and additivity. These four characteristics are defined in Box.1. Moreover, the solution which satisfy these four characteristics is Shapley value only [5].

Box.1 The definitions of total rationality, zero evaluation of null players, symmetry and additivity

1. Total rationality

   Total rationality is to satisfy the following expression.

$$\sum_{i \in C} \phi_i = cfv(C).$$

2. Zero evaluation of null players

   Firstly, we define null player and dummy player.

   A null player satisfies the following expression.

$$cfv(S \cup s_i) = cfv(S), \quad \forall S \subset C - \{c_i\}$$

   A dummy players satisfies the following expression.

$$cfv(S \cup c_i) = cfv(S) + cfv(c_i), \quad \forall S \subset C - \{c_i\}$$

   If player c_i is a null player, he/she is a dummy player.

   If player c_i is dummy player, $\phi_i = cfv(c_i)$. If he/she is null player,$\phi_i = 0$.

3. Symmetry

   When two players, c_i and c_j, satisfy the following expression, they are called to have symmetry.

$$cfv(S \cup c_i) = cfv(S \cup c_j), \quad \forall S \subset C - \{c_i, c_j\}$$

   If the two players are symmetry, the following expression is satisfied.

$$\phi_i = \phi_j$$

4. Additivity

   The following two games, G1 and G2, are composed of same member of players.

$$G_1 = (C, cfv),\ G_2 = (C, cfw)$$

The game (G, u) which has characteristic function u is defined as a sum game of G1 and G2 for given $\forall S \subset C$. cfu is defined as following.

$$cfu(S) = cfv(S) + cfw(S)$$

It is defined as $G = G1 + G2$ or $u = v + w$. $G1$ and $G2$ are called component game.

Shapley value of player c_i in sum game $G = (C, v + w)$ is equivalent to sum of Shapley value of player c_i in component game of the sum game. The following is its expression.

$$\phi_i(cfu) = \phi_i(cfv) + \phi_i(cfw)$$

This property is called additivity.

Nucleolus and Shapley value are used to the problem of not only sharing of profit but also distribution of expenses and decision of fees. Littlechild and Owen decided the usage fee of the airstrip of 11 kinds of airplanes of Birmingham International Airport in Britain from 1968 to 1969 [6]. In this case, the total number of landing and takeoff per year is 13572.

This research makes use of Shapley value to distribute profit to creators which are obtained by making services.

It is expected that creators will make total coalition thanks to the distribution of incomes according to Shapley value. To make creators' total coalition means to allocate tasks to all creators to get maximum profit of services made by them. It allows creators to create a variety of services without redundancy of services which is made in the case that creators can choose services by their own free will. It increases social surplus and creators' profit. This research uses Shapley value as the way to distribute profit because it is expected that various services are made and the distribution of profit from services which satisfies the characters which are shown in Box.1. The following chapter explains to what scope Shapley value can be applied to the distribution of profit obtained from services and what problem would happen through comparisons between other ways of distribution and this way.

Chapter 3 Problems about Sharing Profit

This chapter describes and formulates a problem about distribution of profit from services and shows its example.

3.1 Formulation of a Problem about Distribution of Profit

The following describes a problem about distribution of profit from services and formulates the problem.

This research presupposes that users demand a variety of services and show their demands in the form of money. Creators decide what services each creator makes by comparing and considering the profit and cost when he/she makes the service (Maximization of creators' utility). It is more desirable if creators make more variety of services because society requires them (Maximization of social surplus).

The problem has a set of services $S = \{s_j | 0 \leq j \leq m, j \in \mathbb{N}\}$, the number of members of which is $m+1$ and which users want to make. The value of function u shows a value (demand) of service s_j as $u(s_j)$. Creators' total profit which is obtained when they make a service is the value (demand) of the service. There are creators of which the number is $n + 1$. They are defined as set $C = \{c_i | 0 \leq i \leq n, n \in \mathbb{N}\}$. Creators have costs which are needed to make services. The cost when creator c_i makes service s_j is showed by function $costOfc_i(s_j)$. If the cost which is needed to make a service outweighs the profit (= value or demand) which is obtained from the service, creators do not (can not) make it. Each creator is presumed to be selfish.

All creators commonly understand the values of services and know which service each creator can make when Shapley value is used. Users publicly show the values of services. All creators commonly understand total profit which is obtained from a service because users indicate the demand of the service in the form of money. Which service a creator has the ability to make and which service he does not are common information when Shapley value is used to distribute profit. This is because even if a creator lies that he can make the service and tries to get profit, he has a risk that he has to make the service and is found to have said a lie because he can not make the service actually. Creators honestly declare which service they can make (or which service they can not) by preparing a rule to punish the creator who are found to have said a lie appropriately beforehand. $creatableServices(c_i) \subset S$ is the set of services which the creator c_i have the ability to make.

Each creator's utility is calculated by subtracting the cost of a service from profit which is obtained from the service. If services more than one which have a same function are created, the total profit which creators who created the service get is equal in the case that one creator create the service which have the function. The profit is divided to each creator equally. However, the cost to make the service does not change because the task which one creator has to do to make the service does not change even though other creator makes service which has the same function.

The cost which each creator needs to make the service and the priority order by which they want to make services are private information because creators are selfish and they can say a lie to increase their profit. They have no reason to declare the cost which is needed to make a service and their priority order of services honestly. Hence these two are private information because no one can believe the declaration of the creator's costs to make services and the priority order of services even if he/she declares them.

This research presupposes that the number of services which one creator can make is one at a maximum in order to simplify this problem.

Which service each creator make is expressed as the vector $services = \{(ds_0, \dots, ds_i, \dots, ds_n) | ds_i \in creatableServices(c_i)\}$, the members of which are services. ds_i is the service which creator c_i are going to make. Plural ds_i can be the same service s_j because some creators might make the same functional service. It is possible that all $ds_i (0 \leq i \leq n)$ are the same service s_j.

The goal of this problem is to minimize the absolute value of a gap between ideal social surplus and actual social surplus and to maximize creators' utility. If creators make total coalition hand in hand to maximize social surplus, it is needed that each creator is satisfied his/her profit. Maximizing social surplus means below. It is does not aim to make the best service in many services with a same function. It aims to make not services with a same function but services with different functions. It presupposes that all services with a same function (i.e. machine translation between Japanese and English) have same quality. It does not aim to make a good machine translation between Japanese and English. It aims to make not only machine translation between Japanese and English but also for example machine translation between Japanese and Germany and machine translation between Japanese and Portuguese. Like this, it aims to make multiple services with different functions.

$actualServices = \{(ds_0, \ldots, ds_n)_l | ds_k \in S, 0 \leq k \leq n, l \in \mathbb{N}\}$ is the service which each creator decides to make actually in some way. Function $income$ shows total profit. $income(services)$ is the total profit which is the sum of each creator obtain and is the sum of value of $services$ exclude redundancy of service. $totalCost(services)$ is the total cost which each creator has to spend to make $services$. $(income(actualServices) - totalCost(actualServices))$ is social surplus when creators make $actualServices$. $\max_{services}(income(services) - totalCost(services))$ is ideal social surplus. $incomeOfc_i$ is the value which creator c_i obtain when each creator make the service based on $services$. $incomeOfc_i(services) - costOfc_i(ds_i)$ is the utility of creator c_i.

- Social requirement

  Minimization: $|(income(actualServices) - totalCost(actualServices)) - \max_{services}(income(services) - totalCost(services))|$
- Creator c_i's requirement

  Maximization: $incomeOfc_i(services) - costOfc_i(ds_i)$

3.2 Segmentation of the Problem

The number of $services$ and the number of $creators$ can be presupposed to be same ($n = m$) without loss of generality about this problem about distribution of profit. This is because even if $n \neq m$, the problem can be divided into plural problems which are pairs of vector of $creators$ and vector of $services$ and the number of members of the vector are same($n = m$). The vectors are given by Algorithm 1. It maximizes the number of service S which is made by the creators' set C. Even in the problem in which creators can not make total coalition, the problem can be divided into the problems in which they can make total coalition if characteristic function cfv is super-additive.

Algorithm 1 gets $givenCreators$ which is the set of creators, the number of which is n' and gets $givenServices$ which is the set of services, the number of which is m' (n' and m' are different or creators do not make total coalition). It gives creators which is the set of creators, the number of which is n and gives services which is the set of services, the number of which is m.(n and m is same and creators make total coalition). Algorithm 1 gives services which gives maximum total profit which can be made by $givenServices$ and $givenCreators$. It gives the least number of creators who are necessary to make the services. It gives the coalitions which maximize the profit from the services when $givenCreators$ and $givenServices$ are given. This is because the vector about which service each creator make shown by $AllServices = \{(ds_0, \ldots, ds_k, \ldots, ds_{m'})_l | ds_k \in S, 0 \leq k \leq m', l \in \mathbb{N},$ if $ds_k \notin creatableServices(c_i)$ then c_k won't create $s_k\}$ is the finite set ,the number of which is at most $\#S^{\#C}$. So there exists maximum profit which is obtained by making the services which the vector $(ds_0, \ldots, ds_k, \ldots, ds_m)$ indicates. It also gives the set of creators, whose number is same to the number of the services, who make this service vector which has maximum profit because each creator can make one service by themselves.

It is possible that plural $services$ which give maximum profit exist. It is feasible that each $services$ has plural $creators$.

The number of members of $services$ and the number of members of $creators$ in all combination which is obtained from this algorithm are same. And creators can make total coalition. By the above mentioned discussions, presumption that the number of given services and the number of given creators are same and that creators certainly make total coalition do not lose generality. We presumes that the number of services which users require and the number of creators are same and that creators can make total coalition even if there is no clear statements in the following chapters.

Algorithm 1 Dividing problems

Require: $C, S, u, costOfc_i, creatableServices, givenServices, givenCreators$

Ensure: Vector $servicesAndCreators = \{(services, creators)_l|, l \in \mathbb{N}\}$ such that the number of the services and the number of the creators are equal and that the creators can get max total income from creationg the services which givenCreators can make.

for all $creators = \{creators | creators \subset givenCreators\}$ **do**

  $presentMaxUtility \longleftarrow 0$

  $presentMinNumberOfCreators \longleftarrow$ a value enough big

  for all $services = \{(ds_0, \ldots, ds_i, \ldots, ds_{\#creators})| ds_i \in creatableServices(creators[i])\}$ **do**

    if $presentMaxUtility < getUtility(services)$ **then**

      $presentMinNumberOfCreators \longleftarrow \#creators$

      $presentMaxUtility \longleftarrow getUtility(services)$

      $servicesAndCreators \longleftarrow null$

      $addTo(servicesAndCreators, services, creators)$

    else if $presentMaxUtility == getUtility(services)$ **then**

      if $presentMinNumberOfCreators == \#creators$ **then**

        $addTo(servicesAndCreators, services, creators)$

      else if $presentMinNumberOfCreators > \#creators$ **then**

        $presentMinNumberOfCreators \longleftarrow \#creators$

        $servicesAndCreators \longleftarrow null$

        $addTo(servicesAndCreators, services, creators)$

      end if

    end if

  end for

end for

return $servicesAndCreators$

3.3 Example of the Problem

The following is an example of this problem about distribution of profit from services which this research deals with.

Box.2 shows a concrete example of the above mentioned problem which has 3 creators and 3 services and which creators can make total coalition.

Box.2 Concrete Example of This Problem

- Set of creators C

  $C = \{c_0, c_1, c_2\}$
- Set of services S

  $S = \{s_0, s_1, s_2\}$
- Values (demands) of services

  $u(s_0) = 100, u(s_1) = 30, u(s_2) = 20$
- Services which creators can make
  - $creatableServices(c_0) = s_0, s_1, s_2$
  - $creatableServices(c_1) = s_0, s_1$
  - $creatableServices(c_2) = s_2$
- Costs to make services of each creator
  - $costOfc_0(s_0) = 10, costOfc_0(s_1) = 5, costOfc_0(s_2) = 2$
  - $costOfc_1(s_0) = 20, costOfc_1(s_1) = 10$
  - $costOfc_2(s_2) = 5$

This example is the problem how to allocate 3 services to 3 creators. Each service has the values (demands). The total of the value means the total profit which creators obtain by making services. Each creator has the set of services which he/she can make and has cost to make the service. In this example, Creator c_0 can make service s_0,s_1,s_2. Creator c_1 can make only two service s_0 and s_1. Creator c_2 can make only one service s_2.

Chapter 4 Not Sharing Profit and its Problem

This chapter describes the way to decide services to make and the way to distribute profit based on creators' own free will by which profit is not shared and shows an example of its problem.

4.1 Selections of Services to Make

The following is explanation of the choices of services based on the way that selfish creators select services to make and get profit from the service according to their own free will.

Creators can get the profit which is calculated by dividing demand of each service into the number of creators who make the service which have same function. The value(or demand) of each service which users declare to pay is the total profit which all creators who create the same functional service can get by making it. Even if many creators make the services which have the same function which users require, the profit which they can obtain in total is same. This is because the demand of users does not increase even if creators make many services which have the same function. The total demand of users does not increase and is just divided into the creators who make these services. As a result, the profit which one creator can get from making one service decreases. This research presupposes that the profit of one creator from the services which have the same function is equally divided by the number of creators who make the same functional service.

Creators' utility is calculated by subtracting the cost of making the service from the profit. Creators will make the service which gives maximum utility because this research presupposes that creators are selfish. If creators' utility goes negative, they do not make the service.

Algorithm 2 and Algorithm 3 are algorithms which decide which service creators make based on their own free will. These algorithms decide the service which creators make and distribute the profit from the service equally to the creators who produce same functional services. Algorithm 2 decides the service which maximize creator's utility by considering other creators' selections of service to make. It corresponds to $getBestServices(previousServices)$ in Algorithm 3. Algorithm 3 decides creator's action when other creators' actions are given. It decide new action again and again until this decision converge.

Algorithm 2 getBestServices

Require: $C, S, u, costOfc_i, creatableServices, previousServices$

Ensure: $betterServices = \{(ds_0, \dots, ds_m)_l | ds_k \in S, 0 \leq k \leq m, l \in \mathbb{N}\}$ is expected to obtain a more utility for each creator than previousServices is.

for all $i = \{i | c_i \in C\}$ **do**
  $presentServices \longleftarrow previousServices$
  for all $newDs_i = \{newDs_i \in creatableServices(c_i)\}$ **do**
    $newServices \longleftarrow (ds_1, \dots, ds_{i-1}, newDs_i, ds_{i+1}, \dots, ds_n)$
    $presentUtility \longleftarrow$

$$\begin{cases} getExpectedValueOfUtilityOfc_i(newDs_i), & \text{if } previousServices == null \\ getUtilityOfc_i(presentServices), & \text{if } previousServices != null \end{cases}$$

    if $presentUtility < getUtilityOfc_i(newServices)$ **then**
      $presentServices \longleftarrow newServices$
      $presentUtility \longleftarrow getUtilityOfc_i(newServices)$
    end if
  end for
  $betterServices[i] \longleftarrow presentServices[i]$
end for
return $betterServices$

Algorithm 2 gets the vector of services $previousServices = \{(ds_0, \dots, ds_n)_l | ds_k \in S, 0 \leq k \leq n, l \in \mathbb{N}\}$ which creators were going to make and decides new service which a creator make if there exists the service which has the more utility(profit - cost) than a previous time by considering other creators' action(choices of services) for each creator c_i. If $previousServices$ is $null$, each creator decide a service to make based on the expected value of the utility which is obtained by making the service. $getExpectedValueOfUtilityOfc_i(newDs_i)$ returns the expected value of utility which creator c_i obtains from making service $newDs_i$. $getUtilityOfc_i(presentServices)$ returns the utility which c_i obtains assuming that creators make the service in accordance with $presentServices$.

Algorithm 3 Selections of Services to Make Based on Creators' Own Free Will

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Require: $C, S, u, costOfc_i$

Ensure: $servicesVector = \{(ds_0, \ldots, ds_n)_l | ds_k \in S, 0 \leq k \leq n, l \in \mathbb{N}\}$ is expected to obtain a max utility for each creator.

1: $services \longleftarrow getBestServices(null)$
2: **repeat**
3: $\quad addTo(servicesVector, services)$
4: $\quad previousServices \longleftarrow services$
5: $\quad services \longleftarrow getBestServices(previousServices)$
6: **until** $servicesAreLoopedOrNotChanged(services, servicesVector)$
7: $servicesVector \longleftarrow extractSameOrLoopedServicesVector(services, servicesVector)$
8: **return** $servicesVector$

Algorithm 3 decides services which each selfish creator makes. It gives the vector $servicesVector = \{(ds_0, \ldots, ds_m)_l | ds_k \in S, 0 \leq k \leq, l \in \mathbb{N}\}$, which is the vector of services which offer the maximum expected value of utility to each creator. Algorithm 2 selects the service which gives creator maximum utility if other creators' actions is given. Algorithm 3 runs Algorithm 2 again and again until the return actions converge. If same pattern appears again and again, it detects the loop and gets $servicesVector$.

4.2 Example of Selections of Services and its Problem

The following is an example of how to select the service based on creators' own free will and how to distribute the profit and its problem in the case of 3.3. Table 1 describes each creator's utility and social surplus in each vector of services, which creators are going to make. ds_0 is the service which c_0 want to make. ds_1 is the service which c_1 want to make. ds_2 is the service which c_2 want to make.

Table 1: Utilitieies and social surplus based on each creator's own will

ds_0	ds_1	ds_2	Social surplus	Utility of c_0	Utility of c_1	Utility of c_2
s_0	s_0	s_2	120-10-20-5=85	100/2-10=40	100/2-20=30	20-5=15
s_0	s_1	s_2	100+30+20-10-10-5=125	100-10=90	30-10=20	20-5=15
s_1	s_0	s_2	30+100+20-5-20-5=120	30-5=25	100-20=80	20-5=15
s_1	s_1	s_2	30+20-5-10-5=30	30/2-5=10	30/2-10=5	20-5=15
s_2	s_0	s_2	20+100-2-20-5=93	20/2-2=8	100-20=80	20/2-5=5
s_2	s_1	s_2	20+30-2-10-5=33	20/2-2=8	30-10=20	20/2-5=5

Creators decide the services to make based on each creator's utility which this table shows and which is reckoned by each vector of services. Firstly, each creator decides the service which is expected for the creator to be likely to obtain maximum value of profit. Then, each creator decides the service which has more profit than the service which he/she has decided in a previous time.

We describe how creator c_0 decides the service to make. The expected value of utility when creator c_0 decides to make service s_0 is 65. This reason is the following. If creator c_1 makes service s_0 and creator c_2 makes service s_2, his/her utility is 40. If creator c_1 makes s_1 and creator c_2 makes s_2, his/her utility is 90. Hence, expected value of his/her utility is $(40 + 90)/2 = 65$. The expected value of utility when creator c_0 decides to make service s_1 is 15. This is because, if creator c_1 makes service s_1 and creator c_2 makes service s_2, his/her utility is 20 and if creator c_1 makes s_0 and creator c_2 makes s_2, his/her utility is 10. Hence, expected value of his/her utility is $(20+10)/2 = 15$. The expected value of utility when creator c_0 decides to make service s_2 is 8. This is because, if creator c_1 makes service s_0 and creator c_2 makes service s_2, his/her utility is 8 and if creator c_1 makes s_1 and creator c_2 makes s_2, his/her utility is 8. Hence, expected value of his/her utility is $(8+8)/2 = 8$. As a result, creator c_0 decides to make service s_0 which has maximum expected value of utility. In the same way, c_1 decides to make service s_0 and c_2 decide to make service s_2 based on the expected value of utility.

As a result, the vector of services which each creator makes based on the expected values of utility is $(ds_0, ds_1, ds_2) = (s_0, s_0, s_2)$. Then, each creator chooses the service which gives more utility considering other creators' decision, which the vector $(ds_0, ds_1, ds_2) = (s_0, s_0, s_2)$ gives. This process continues until no one change the service to make or same pattern appears.

The utility of creator c_0 is 40 when he/she makes service s_0, 20 when he/she makes service s_1, or 8 when he/she makes service s_2 because creator c_1 makes service s_0 and creator c_2 makes service s_2. Hence, creator c_0 continues to choose to make service s_0. In the same way, creator c_1 continues to make service s_0. Creator c_2 continues to make service s_2. Therefore, creators are going to make $actualServices = (s_0, s_0, s_2)$ based on their free will because the services which creators make do not change from the previous process.

The vector of services creators make is $actualServices = (s_0, s_0, s_2)$ based on their free will. This decision has a problem. The set of services which users require is the set $S = \{s_0, s_1, s_2\}$. No creator makes service s_1 and provides it to the society. It causes the dilemma that social surplus decreases even though each creator selfishly decides the service to make and various services is not created.

Chapter 5 Sharing Profit by Shapley Value

This chapter describes the way to solve the problem shown in Chapter 3 by applying Shapley value to it and explains why this research applies Shapley value to it, why Shapley value is useful to create a variety of services and how to apply Shapley value to it. We shows a flaw of the way to distribute profit according to Shapley value and in which case choices of services to make based on creators' own free will is better than based on Shapley value.

5.1 Reasons of Applying Shapley Value

The following are the reasons why application of Shapley value to the problem of distribution of profit can create a variety of services.

Total profit which creators obtain by making services cooperatively is more than the total profit which creators obtain by creators' free will because characteristic function cfv is super-additive. Distribution of profit according to Shapley value satisfies individual reasonability and total reasonability because characteristic function cfv is super-additive and they are assured by properties of Shapley value shown in 2.4. Due to this, it is expected that each creator does not choice by his/her own free will and makes total coalition. He/she selects the service to make by cooperating with other creators in order not to make same service.

Creators' total coalition and selections which service creators make by cooperating with other creators in order not to make same services can create a variety of services. It is presumable that social surplus and each creator's utility increase because total profit which is obtained from services increases.

Four characteristics which distribution according to Shapley value satisfies shown in 2.4 (total rationality, zero evaluation of null players, symmetry and additivity) are necessary for distribution of profit because of the following reasons.

Total rationality

To distribute all profit to creators.

Zero evaluation of null players

Not to distribute profit to a creators who do not make a profit.

Symmetry

To distribute same profit to creators who have same ability to make services.

Additivity

Creators' profit is sum of profits of each process though they make services in plural process.

From these reasons, this research applies Shapley value to the way to distribute profit from services in order to make a variety of services and to maximize social surplus and each creator's utility.

5.2 Way to Apply Shapley Value

The following is the way to apply Shapley value to distribution of profit. Applying Shapley Value needs transforming the problem of distribution of profit from services into a game in coalitional form with transferable utility, which is defined as (C, v). Concretely, defining characteristic function cfv from data shown in 3.1 means transforming the problem of distribution of profit into a game in coalitional form with transferable utility, to which Shapley value can apply. By transforming into the game, it is possible automatically to calculate profit of each creator because of the way to calculate Shapley value.

Which service a creator can make and which service he/she can not are supposed to be common information if Shapley value is applied to the problem of distribution of profit. This is because even if a creator lies that he can make the service and tries to get profit, he has a risk that he has to make the service and is found to have said a lie because he can not make the service actually. Creators honestly declare which service they can make (or which service they can not) by preparing a rule to punish the creator who are found to have said a lie appropriately beforehand.The set of services which creator c_i can make is given by $createableServices(c_i)$.

Algorithm 4 is the way to evaluate super-additive characteristic function $cfv(V)$, which returns profit of creators' subset $V \subseteq C$. *coalitionSet* is all possible set of coalitions including coalition V and all creators. *sequence* is the

Algorithm 4 Calculation of Characteristic Function $cfv(V)$

Require: $C, S, creatableServices, V \subseteq C$

for all $coalitionSet = \{V, W_1, \ldots, W_k, \ldots, W_l | W_k \subseteq C, V \bigcup W_1 \bigcup \cdots \bigcup W_l = C, V \bigcap W_1 \bigcap \cdots \bigcap W_l = \phi\}$ **do**
    for all $sequence = \{c_{i_1}, \ldots, c_{i_h}, \ldots c_{i_n} | c_{i_h} \in C, c_{i_h} \neq c_{i_{h'}}\}$ **do**
        $services \longleftarrow getBestServices(null, coalitionSet, sequence)$
        repeat
            $addTo(servicesVector, services)$
            $previousServices \longleftarrow services$
            $services \longleftarrow getBestServices(previousServices, coalitionSet, sequence)$
            $loopedServicesVector \leftarrow loopedOrNotChanged(services, servicesVector)$
        until $loopedServicesVector! = null$
        $averageOfOneSequence \longleftarrow getAverage(loopedServicesVector, V)$
        $addTo(averageVectorOfSequence, averageOfOneSequence)$
    end for
    $averageOfOneCoalition \longleftarrow getAverage(averageVectorOfSequence)$
    $addTo(averageVectorOfCoalition, averageOfOneCoalition)$
end for
$averageIncomeOfV \longleftarrow getAverage(averageVectorOfCoalition)$
return averageIncomeOfV

order of creators to choose a service to make.

$getBestServices(previousServices, coalitionSet, sequence)$ gives the vector of services *services* which creators are going to make and which is the best choices that each creator think. In this function, creators choose the service that he/she think to get max utility in the order *sequence* when the vector of services *previousServices* which other creators make are given. A creator chooses the service from the services which he has the ability to make and which have not been made yet by other creators when his/her turn comes. He/she selects the next *services* so as to maximize profit of coalition which he/she takes part in.

The value of characteristic function $cfv(V)$ is the average of expected value of maximum profit which coalition V can obtain in all *coalitionSet* and in all *sequence*.

Each creator randomly gets the services from possible total coalition and makes it. Therefore total coalition is formed and a variety of services is created.

5.3 Example of Applying Shapley Value

The following is an example of the way to distribute profit by using Shapley value based on a characteristic function which is defined in 5.2 in the case of the example shown in 3.3.

The way to evaluate characteristic function $cfv(V)$ concretely, which returns the profit of one coalition $V = \{V | V \subset C\}$, is as follows.

All of creators' orders are six patterns (c_0, c_1, c_2), (c_0, c_2, c_1), (c_1, c_0, c_2), (c_1, c_2, c_0), (c_2, c_0, c_1), (c_2, c_1, c_0). Evaluating maximum profit of V in each of these 6 orders and take the average of them. The value of characteristic function $cfv(V)$ is this expected value.

$cfv(V)$ is evaluated by calculating each creator's choices of the service to make in each order and in each possible set of coalitions. Table 2 is selections of services in the cace of the each service $ds_i = \{ds_i | ds_i \in S, ds_k \neq ds_l, 0 \leq i, k, l, \leq 2\}$ which creators make and which is determined in each of above-mentioned possible orders and in each of possible sets of coalitions.

Possible sets of coalitions are 5 patterns that are $\{\{c_0\}, \{c_1\}, \{c_2\}\}$, $\{\{c_0, c_1\}, \{c_2\}\}$,

Table 2: $ds_i = \{ds_i | ds_i \in S, ds_k \neq ds_l\}$ in each set of coalitions and sequence.

set of coalitions	sequence	ds_0	ds_1	ds_2
$\{\{c_0\},\{c_1\},\{c_2\}\}$	(c_0, c_1, c_2)	s_0	s_1	s_2
	(c_0, c_2, c_1)	s_0	s_1	s_2
	(c_1, c_0, c_2)	s_1	s_0	s_2
	(c_1, c_2, c_0)	s_1	s_0	s_2
	(c_2, c_0, c_1)	s_0	s_1	s_2
	(c_2, c_1, c_0)	s_1	s_0	s_2
$\{\{c_0, c_1\},\{c_2\}\}$	(c_0, c_1, c_2)	s_0	s_1	s_2
	(c_0, c_2, c_1)	s_0	s_1	s_2
	(c_1, c_0, c_2)	s_1	s_0	s_2
	(c_1, c_2, c_0)	s_1	s_0	s_2
	(c_2, c_0, c_1)	s_0	s_1	s_2
	(c_2, c_1, c_0)	s_1	s_0	s_2
$\{\{c_0\},\{c_1, c_2\}\}$	(c_0, c_1, c_2)	s_0	s_1	s_2
	(c_0, c_2, c_1)	s_0	s_1	s_2
	(c_1, c_0, c_2)	s_1	s_0	s_2
	(c_1, c_2, c_0)	s_1	s_0	s_2
	(c_2, c_0, c_1)	s_0	s_1	s_2
	(c_2, c_1, c_0)	s_1	s_0	s_2
$\{\{c_0, c_2\},\{c_1\}\}$	(c_0, c_1, c_2)	s_0	s_1	s_2
	(c_0, c_2, c_1)	s_0	s_1	s_2
	(c_1, c_0, c_2)	s_1	s_0	s_2
	(c_1, c_2, c_0)	s_1	s_0	s_2
	(c_2, c_0, c_1)	s_0	s_1	s_2
	(c_2, c_1, c_0)	s_1	s_0	s_2
$\{\{c_0, c_1, c_2\}\}$	(c_0, c_1, c_2)	s_0	s_1	s_2
	(c_0, c_2, c_1)	s_0	s_1	s_2
	(c_1, c_0, c_2)	s_1	s_0	s_2
	(c_1, c_2, c_0)	s_1	s_0	s_2
	(c_2, c_0, c_1)	s_0	s_1	s_2
	(c_2, c_1, c_0)	s_1	s_0	s_2

$\{\{c_0\},\{c_1,c_2\}\}$, $\{\{c_0,c_2\},\{c_1\}\}$, $\{\{c_0,c_1,c_2\}\}$. Creators choose the service to make in each of these five possible sets of coalitions and in each of above orders. The example in 3.3 is easy because the services to make in each order are same in any sets of coalitions.

The following is an example of a case that sets of coalitions is $\{\{c_0\},\{c_1\},\{c_2\}\}$. Each creator chooses the service which gives him/her maximum profit in his/her turn because each coalition is consisted of one creator. In the case that an order is (c_0,c_1,c_2), creator c_0 chooses s_0, which has maximum profit in all services. Creator c_1 chooses service s_1, which has maximum profit in remaining services. Creator c_2 finally chooses the rest, service s_2. In the case that an order is (c_2,c_1,c_0), c_2 chooses service s_2 because he/she has the ability to make service s_2 only. Creator c_1 chooses service s_0, which has maximum profit in remaining services. Lastly, creator c_0 chooses the rest, service s_1. Do same things in all orders and choose the services which creators make in each order.

Because creator c_0 makes service $s_0, s_0, s_1, s_1, s_0, s_1$ in each order, expected value of profit of coalition $\{c_0\}$ is $(100+100+30+30+100+30)/6 = 65$. In the same way, expected value of profit of coalition $\{c_1\}$ is $(30+30+100+100+30+100)/6 = 65$. Expected value of profit of coalition $\{c_2\}$ is $(20+20+20+20+20+20)/6 = 20$.

The following is an example of a case that a coalition is consisted of multiple creators and that is $\{\{c_0,c_1\},\{c_2\}\}$. In the case that an order is (c_0,c_1,c_2), creator c_0 can choose one service from all services s_0, s_1, s_2. If creator c_0 chooses service s_0, creator c_1 chooses service s_1 because the rest of services which creator c_1 can make are s_1 only. Creator c_2 chooses service s_2. Utility which coalition $\{c_0,c_1\}$ gets is 130. If creator c_0 chooses service s_1, creator c_1 chooses service s_0 because the rest of services which creator c_1 can make are s_0 only. Creator c_2 chooses service s_2 only. Utility which coalition $\{c_0,c_1\}$ gets is also 130. If creator c_0 chooses service s_2, creator c_1 can choose the rest of services s_0 and s_1. Utility which coalition $\{c_0,c_1\}$ gets is less than 130 whether creator c_1 chooses service s_0 or s_1. Therefore, creator c_0 does not choose service s_2. In this way, creators choose the services which maximize total profit of their coalition to which they belong in each order.

In the case that sets of coalitions are $\{\{c_0, c_1\}, \{c_2\}\}$ and an order is (c_0, c_1, c_2), coalition $\{c_0, c_1\}$ makes services $\{s_0, s_1\}$ and gets profit of 130 and coalition $\{c_2\}$ makes service $\{s_2\}$ and gets profit of 20. In the same way, consider creators' choices of services in each of the rest five orders and evaluate expected value of profit.

The following is the way to evaluate $cfv(c_0)$. Coalition $\{c_0\}$ is consisted by two sets of coalitions that are $\{\{c_0\}, \{c_1\}, \{c_2\}\}$ and $\{\{c_0\}, \{c_1, c_2\}\}$. To calculate $cfv(c_0)$, evaluate profit which coalition $\{c_0\}$ gets in each six order and in each of two sets and take the average of them.

Firstly we think the case that the sets of coalitions is $\{\{c_0\}, \{c_1\}, \{c_2\}\}$ and evaluate the average of profit of coalition $\{c_0\}$. In the case that an order is (c_0,c_1,c_2), creator c_0 can make service s_0 and gets profit of 100. In the case that an order is (c_0,c_2,c_1), creator c_0 can make service s_0 and gets profit of 100. In the case that an order is (c_1,c_0,c_2), creator c_0 can make service s_1 and gets profit of 30. In the case that an order is (c_1,c_2,c_0), creator c_0 can make service s_1 and gets profit of 30. In the case that an order is (c_2,c_0,c_1), creator c_0 can make service s_0 and gets profit of 100. In the case that an order is (c_2,c_1,c_0), creator c_0 can make service s_1 and gets profit of 30. In the same way, evaluate profit in the case that the sets of coalitions $\{\{c_0\}, \{c_1, c_2\}\}$ and evaluate expected value. As a result, $cfv(c_0) = ((100 + 100 + 30 + 30 + 100 + 30)/6) + (100 + 100 + 30 + 30 + 100 + 30)/6)/2 = 65$.

In the same way, each characteristic function cfv is as follows. $cfv(c_1) = 65$, $cfv(c_2) = 20$, $cfv(c_0, c_1) = 130$, $cfv(c_0, c_2) = 85$, $cfv(c_1, c_2) = 85$, $cfv(c_0, c_1, c_2) = 150$

It is possible to evaluate distribution of profit to each creator automatically by Shapley value because characteristic function $cfv(V)$ is determined for all subset V in creators' set C. Creator c_0 gets distribution of profit of 65. Creator c_1 gets distribution of profit of 65. Creator c_2 gets distribution of profit of 20.

Which service each creator actually makes is determined randomly from possible sets of total coalition. In this example, possible sets of total coalition are two patterns, (s_0, s_1, s_2) and (s_1, s_0, s_2). One of them is chosen in equally probability.

Expected values of creators' utility are as follows. Creator c_0's expected value of utility is 57.5 because the expected value of his/her cost is $(10+5)/2 = 7.5$. Creator c_1's expected value of utility is 50 because the expected value of his/her cost is $(20 + 10)/2 = 15$. Creator c_2's expected value of utility is 15 because the expected value of his/her cost is 5.

5.4 Example of Problem of Applying Shapley Value

The following is the example of applying Shapley value which is using above-mentioned characteristic function cfv.

Consider the case that creator c_1's cost to make service s_0 is $40(costOfc_1(s_0) = 40)$ in the example shown in 3.3. In this case, though choices of services by creators are based on their free will, creator c_1 chooses to make s_1. As a result, all services are created.

Following is the reason why creator c_0 chooses to make the service s_0 and creator c_1 chooses to make the service s_1.

In the case that creator c_1 makes service s_1 and creator c_2 makes service s_2, utility of creator c_0 is 90 if he/she makes service s_0, 10 if he/she makes service s_1 and 8 if he/she makes service s_2. In this case, creator c_0 can get maximum utility if he/she makes service s_0.

In the case that creator c_0 makes service s_0 and creator c_2 makes service s_2, utility of creator c_1 is 10 if he/she makes service s_0 and 20 if he/she makes service s_1. As a result, creator c_1 chooses to make service s_1 by considering other creators' selections.

If creators distribute profit according to Shapley value, creator c_0, who has higher ability than creator c_1 has, has to transfer profit to creator c_1 unnecessarily. Creator c_0 has dissatisfaction and withdraw from the way to distribute profit by Shapley value.

Creators can make more social surplus by making total coalition (creators cooperate and decide who makes which service). In order to make total coalition, it is needed that all creators do not have dissatisfaction toward their utility (difference between distributed profit and cost to make service). Operators of systems which decide who makes which service want to choose the method to distribute profit in which creators make variable services and much social surplus by making total coalition. If we always apply Shapley value, the above-mentioned problem causes.

By applying Shpaley value, it is expected that creators make total coalition. However, it is not always applicable. Shapley value makes it possible to avoid making services with a same function and to increase social surplus because each creator can make other services. It is likely that creators do not have dissatisfaction by increasing distributed profit to each creator because total profit also increases. However, there might be the case that creators get less profit by applying Shapley value. It is the case that creators ' preferences of services to make are different. Some creators get less profit by applying Shapley value because they have to transfer their profit unnecessarily. This is because all creators make different services even if they do not distribute profit. In this case, it is impossible to make total coalition by applying Shpley value because such creators have dissatisfaction.

This research defines how much each creator wants to make a same service or a different service as similarity of preference and studied how much similarity makes it impossible to apply Shapley value. It uses cosine similarity of costs to make services as similarity of preference. If similarity is low, it is likely that services which each creator want to make (or, services which gives maximum utility to each creator) are different because there is big difference of costs to make services among creators. On the other hand, if similarity is high, it is likely that each creator want to make the same service. The case that Shapley value is inapplicable is the case that similarity is low because it is inapplicable in the case that each creator makes a different service. Therefore this research considered that operators of systems use similarity as criterion to decide the method to distribute profit under each condition. This research studied which way to distribute profit is applicable in each similarity by simulations in Chapter 6.

Chapter 6 Simulations

This chapter demonstrates the change of creators' utility and social surplus due to the change of the number of creators and services and due to the change of similarities between creators by working on simulations. This research works on simulations of the three ways by which creators choose the services to make and distribute profit. Three ways are the ways that is the way based on their free will, that is the way based on Shapley value and that is the way based on distributing equally. We show creators' utility and social surplus of each way in graphs by horizontal axis being a mean of similarities between creators.

6.1 Settings of Simulations

The following is the settings of simulations.

Settings of possible services to make are as follows. The number of services (which is same as the number of creators) is from two to four. This research works on simulations in each case of the number of services. Each service has the value (demand) which is determined by random numbers of uniform distribution of which higher limit is 100 and lower limit is the number of creators that is $\#C$. The reason why lower limit is the number of creators $\#C$ is because even though all creators make the service, they can get profit of at least one. The value (demand) of service s_j is evaluated by $u(s_j)$.

Settings of creators are as follows. The number of creators (which is same as the number of services) is from two to four. This research works on simulations in each case of the number of creators. Creators have the costs to make services. The costs are determined by random number of uniform distribution of which higher limit is 100 and lower limit is 1. The cost which creator c_i needs to make service s_j is expressed as $costOfc_i(s_j)$. If $costOfc_i(s_j)$ outweighs $u(s_j)/\#C$, creator c_i can not make service s_j. If not, he/she can make. Due to this setting, no creator makes a deficit by making possible services. This is because when creator c_i make service s_j, the profit which he/she gets is at least $u(s_j)/\#C$, when all other creators make the same service. Creators have the list of services which they can make which is determined by the above-mentioned step. The list is denoted as $creatableServices(c_i)$. How many services creators can make and which service they can make is set by random number of uniform distribution. Each creator presumed to have at least 1 possible service to create. This simulation presupposes that creators can make total coalition and that there is at least one allocation of services by which all services can be produced.

Creator c_0, creator c_1, creator c_2 and creator c_3 are ranked in descending order of the average of their utility to get in possible total coalitions. The average of their utility in possible total coalitions is the average of utility which creators can obtain by making services (which is presumed to be made only by him/her) in all patterns by possible total coalitions. In the example in 3.3, all of the patterns by possible total coalitions are (s_0, s_1, s_2) and (s_1, s_0, s_2). Creator c_0 makes service s_0 or s_1. Take the average of utility when creator c_0 makes each of these services by him/her only. The average of creator c_0's utility in possible total coalition is $((100 - 10) + (30 - 5))/2 = 57.5$. Because creator c_1 makes service s_0 or s_1, the average of creator c_1's utility in possible total coalition when creator c_1 makes each of these services by him/her is $((30-10)+(100-20))/2 = 50$. Because creator c_2 makes service s_2, the average of creator c_2's utility in possible total coalition when creator c_2 makes the service by him/her is $20 - 5 = 15$. In actual simulations, after determining the values of services and the costs of services by random number of uniform distribution, creators' orders are arranged in descending order of their average utility in possible total coalition. So, these creators are redefined as creator c_0, creator c_1, creator c_2 and creator c_3.

Similarity of creators is defined by applying cosine similarity to the cost of making services. Cosine similarity of creator c_{i_1} and creator c_{i_2} is evaluated by the following expression (7).

$$similarity(c_{i_1}, c_{i_2}) = \frac{\sum_{k=0}^{n-1} costOfc_{i_1}(s_k) \times costOfc_{i_2}(s_k)}{\sqrt{\sum_{k=0}^{n-1} costOfc_{i_1}(s_k)^2} \times \sqrt{\sum_{k=0}^{n-1} costOfc_{i_2}(s_k)^2}} \quad (7)$$

In the graphs, the value of horizontal axis is the average of similarities between creators which is arranged in ascending order in each trial of simulations. The value of longitudinal axis is the average of utility which is taken in a regular interval of the similarity. Similarity between creators is evaluated by expression (7). The graphs arrange creators' utility and social surplus in ascending order of the mean of similarities of the creators if there are more than two creators. The graphs separate similarity at 0.05 intervals and take the average of creators' utilities and social surplus in each interval.

We simulated the way to distribute profit based on creators' own will, the way to distribute profit based on Shapley value and the way to distribute profit equally. As for the way to distribute profit equally, allocation of services to create is decided in order to make all services, which is same as the way to distribute profit based on Shapley value. The gap is that profit which creators obtain is distributed equally to all creators. The following is an example of the way to distribute profit equally in 3.3. Creators make all services $\{s_0, s_1, s_2\}$ and get profit of $100 + 30 + 20 = 150$ in total because they choose services so as to make all services by making total coalition. Each creator's profit is $150/3 = 50$ because this total profit is equally distributed to each creators. The costs of making services are same as the costs in the case that profit is distributed based on Shapley value because creators make total coalition and choose services so as to make all services. Combinations of possible total coalitions are two patterns, (s_0, s_1, s_2) and (s_1, s_0, s_2). One of them is chosen at equal probability. Expected value of creator c_0's utility is $50 - 7.5 = 42.5$ because expected value of his/her cost of making services is $(10 + 5)/2 = 7.5$. Expected value of creator c_1's utility is $50 - 15 = 35$ because expected value of his/her cost of making services is $(20 + 10)/2 = 15$. Expected value of creator c_2's utility is $50 - 5 = 45$ because expected value of his/her cost of making services is 5.

6.2 Results of Simulations

The following is the results of simulations of various services and creators. This research works on simulations of the case that both of the number of creators and the number of services are two, the case that both of the number of creators and the number of services are three and the case that both of the number of creators and the number of services are four. This research focuses on utility of creator c_0, who has the highest ability in all creators, and social surpluses.

From the results of simulations, absolute value of gap between social surpluses in the case that profit is distributed based on Shapley value is less than those in the case that creators choose services based on their own will in any case that both of the number of creators and the number of services are from two to four. When both of the number of creators and the number of services are three or four, utility of creator c_0 by Shapley value is always the highest. When both of the number of creators and the number of services are two and creators are dissimilar, utility of creator c_0 by their own will is the highest. If creators are similar, utility of creator c_0 by Shapley value is the highest.

6.2.1 Number of Creators and Services Are Two

The following is the results of simulations in the case that both of the number of creators and the number of services are two.

Figure 1 shows utility of creators and gap between actual social surplus and ideal social surplus from the results of the simulation. It takes the average of creators' utility and gap between social surpluses by width of similarity 0.05 as one interval and running 1500 trials per one interval. This research focuses on gap between social surpluses and on utility of creator c_0

If creators are dissimilar, utility of creator c_0 in the case that creators choose services based on their own will is higher than those in the case that profit is distributed based on Shapley value (and distributed equally). If creators are similar, utility of creator c_0 in the case that profit is distributed based on Shapley value (and distributed equally) becomes higher than those in the case that creators choose services based on their own will. If creators are dissimilar, creator c_0 drop out from the way to use Shapley value because he/she gets less profit in the case that profit is distributed based on Shapley value. Absolute value of gap between social surpluses in the case that profit is distributed based on Shapley value (and distributed equally) is less than those in the case that creators choose services based on their own will regardless of similarity of creators.

We pick up gap between ideal social surplus and actual social surplus which

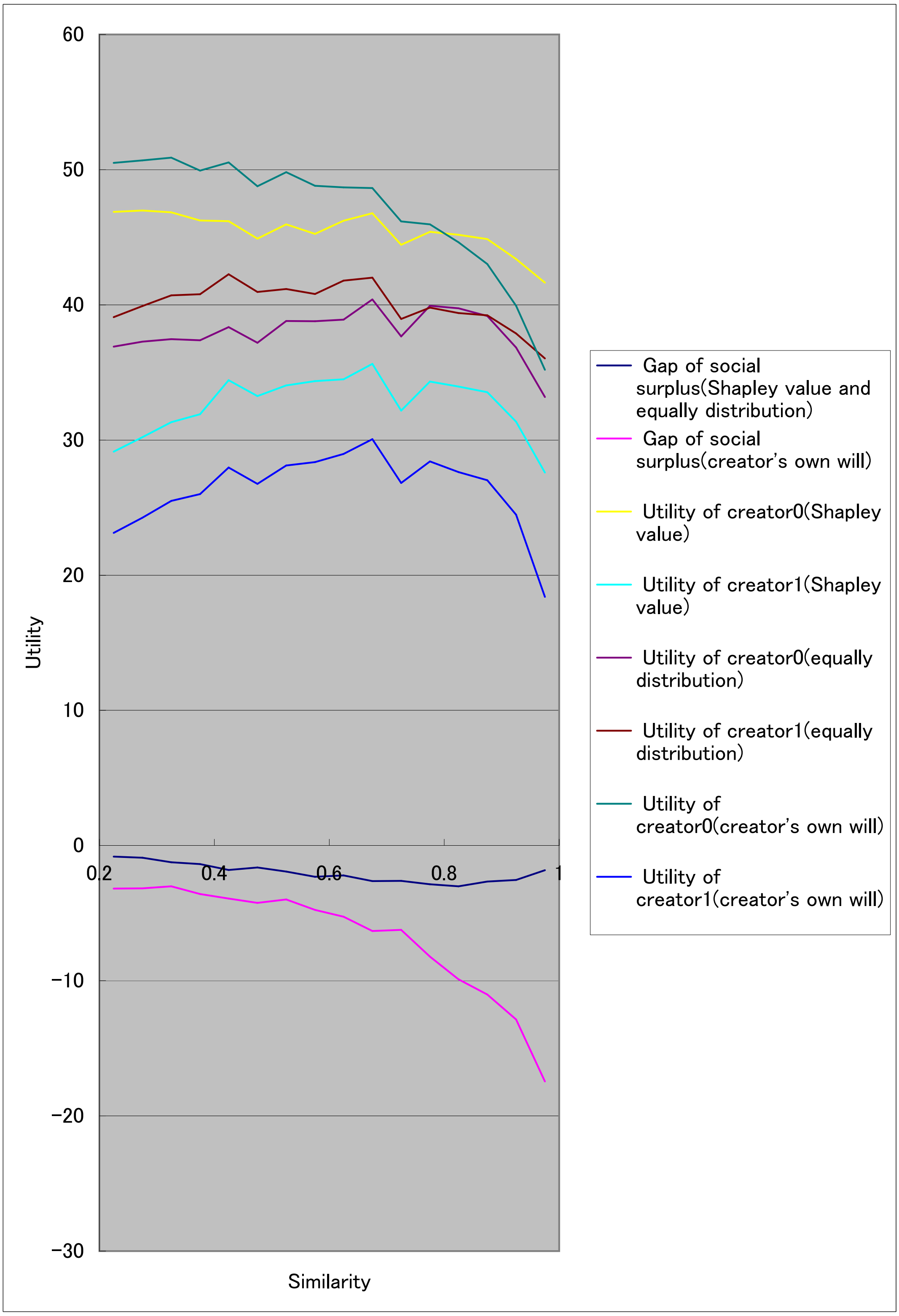

Figure 1: Utility and gap of social surplus of the simulation by 2 creators and 2 services

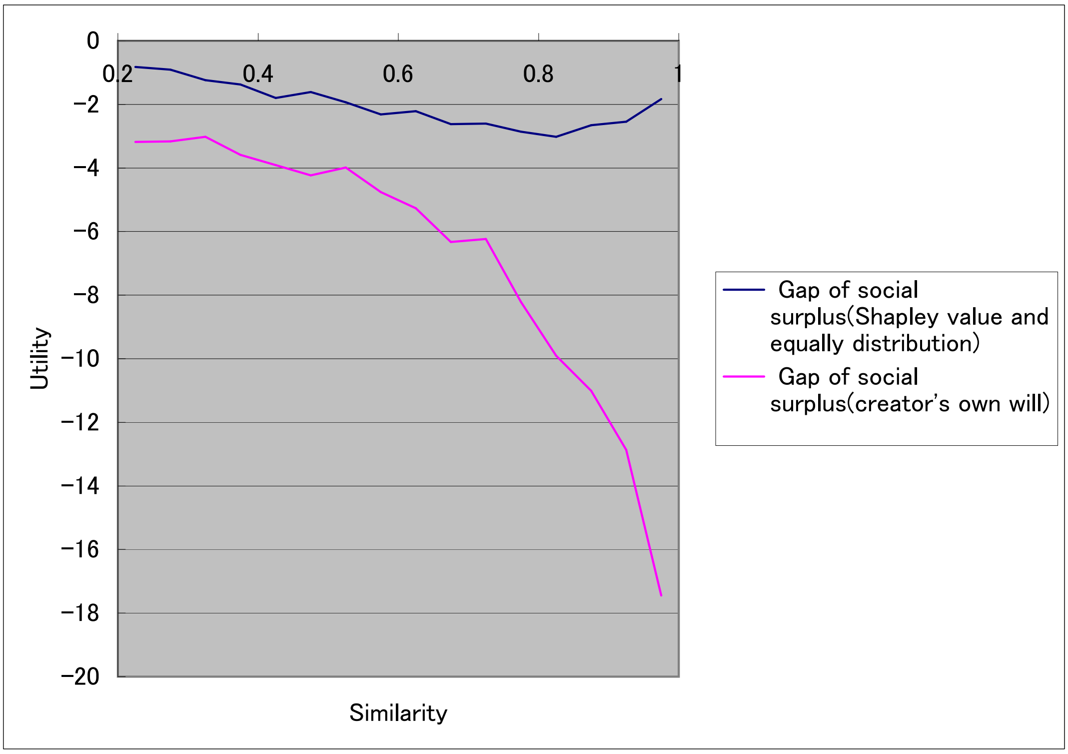

Figure 2: Gap of social surplus of the simulation by 2 creators and 2 services

is determined by the results of simulations actually in each way of distribution of profit (Figure 2).

Social surplus by Shapley value and social surplus by equally distribution is always same. This is because creators make total coalition and choose services to make so as to make all services in both cases. Gaps of social surplus are same because total profit and expected value of the cost are same. Expected values of each creator's profit are different between the way by Shapley value and the way by equally distribution.

Social surplus in the case that profit is distributed based on Shapley value (and distributed equally) is always higher than those in the case that creators choose services based on their own will. In the case that creators choose services based on their own will, they do not necessarily make all services because they decide services freely. On the other hand, in the case that profit is distributed based on Shapley value (and distributed equally), creators make a variety of services and social service increases because it is thought that creators surely make total coalition and all services are created. The reason why absolute value of gap of social surplus by creators' own will becomes bigger as creators become similar is because creators think that the highest utility is obtained by creating the same service and concentrate on profitable services if they are similar. The defect shown in 4.2 happens.

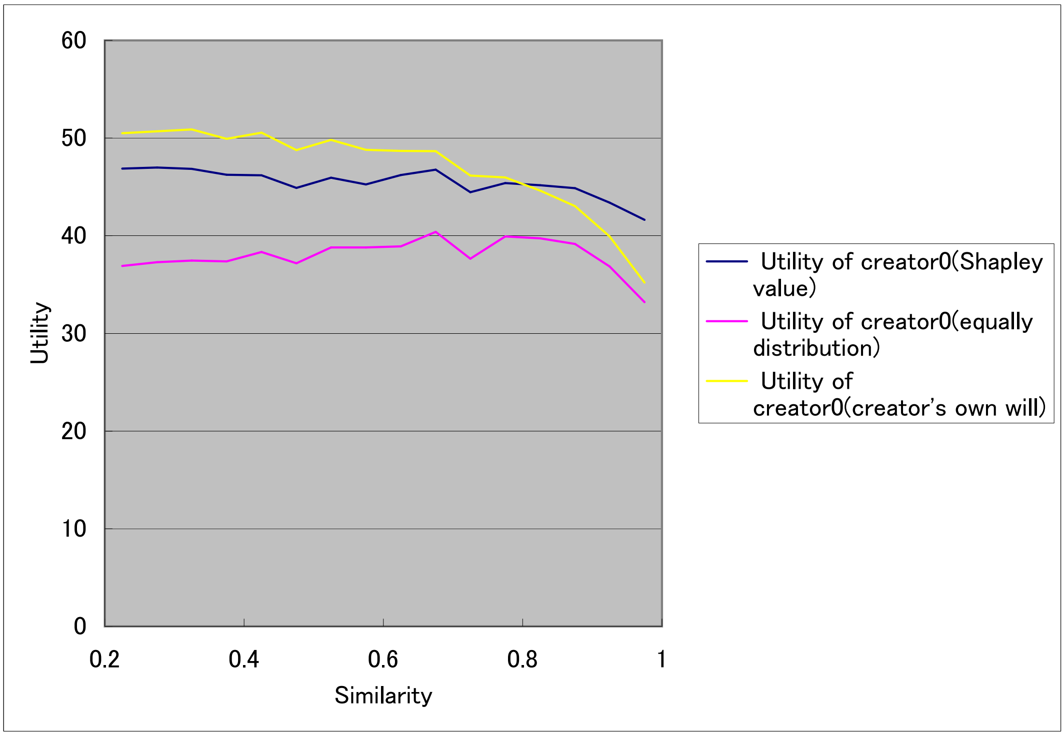

Figure 3: Utility of creator0 of the simulation by 2 creators and 2 services

We pick up utility of creator c_0, who is the most competent in each way of distribution (Figure 3). Utility of creator c_0 by equally distribution is the least. This is because contribution of creator c_0 does not affect his/her profit because profit is distributed equally regardless of creators' ability (which service they can make and get utility). If creators are dissimilar, creators get higher profit by their own will than by Shapley value. However, if they become similar, profit in the case that profit is distributed based on Shapley value becomes higher than those in the case that creators choose services based on their own will. If creators are similar, creator c_0 can gets more profit even if he/she transfers his/her profit in order that other creators make other services because other creators make the same service as creator c_0 without it. On the other hand, if creators are dissimilar, creator c_0 has to transfer his/her profit to other creators in the case that profit is distributed based on Shapley value though the services which they make are basically different. If creators are dissimilar, utility of creator c_0 in the case that profit is distributed based on Shapley value is less than those in the case that creators choose services based on their own will because he/she has to transfer his/her profit unnecessarily. In short, the problem shown in 5.4 happens.

It is desirable that creators distribute profit based on Shapley value because they produce high social surplus and make a variety of services. But Creator c_0, who is the most competent, will not join the way to distribute profit based on Shapley value and will choose the way based on their own will because he/she can expect more utility in the case that he/she choose services based on his/her own will. In the case that both of the number of creators and the number of services are two and that creators are dissimilar, the way to use Shapley value is inapplicable to the problem.

6.2.2 Number of Creators and Services Are Three and Four

The following is the results of simulations in the case that both of the number of creators and the number of services are three and four.

Figure 4 and Figure 5 shows utility of creators and gap between actual social surplus and ideal social surplus from the results of simulations. In the case that both of the number of creators and the number of services are three, it takes the average of creators' utility and gap between social surpluses by width of similarity 0.05 as one interval and running 1500 trials per one interval. Figure A.1 shows variance of similarity in each interval. In the case that both of the number of creators and the number of services are four, it takes the average of creators' utility and gap between social surpluses by width of similarity 0.05 as one interval and running 1000 trials per one interval. As an appendix, Figure A.2 shows variance of similarity in each interval. This research focuses on the gap between social surplus and it focuses on the utility of creator c_0.

In the case that both of the number of creators and the number of services are three and four, absolute value of gap between social surpluses by Shapley

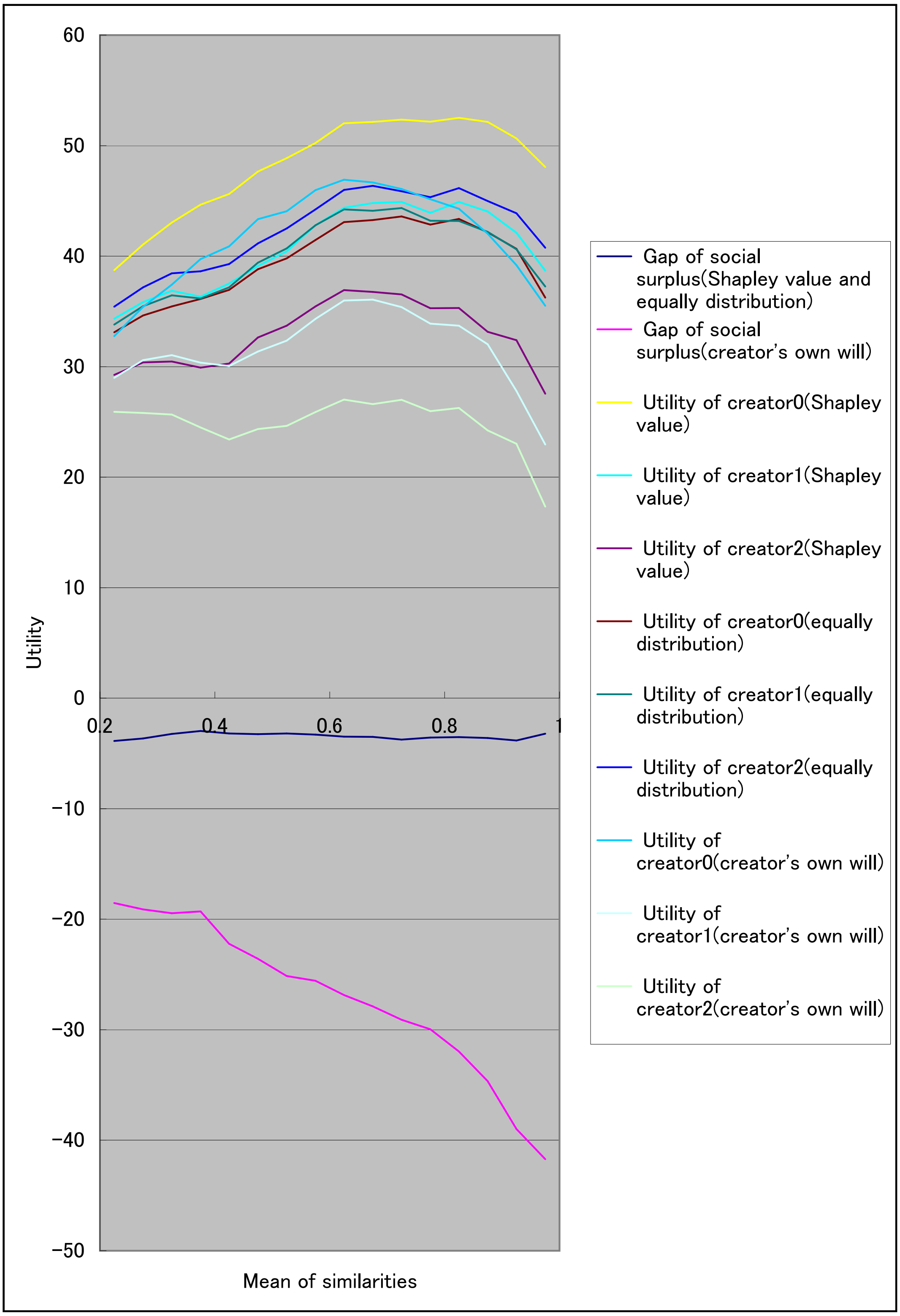

Figure 4: Utility and gap of social surplus of the simulation by 3 creators and 3 services

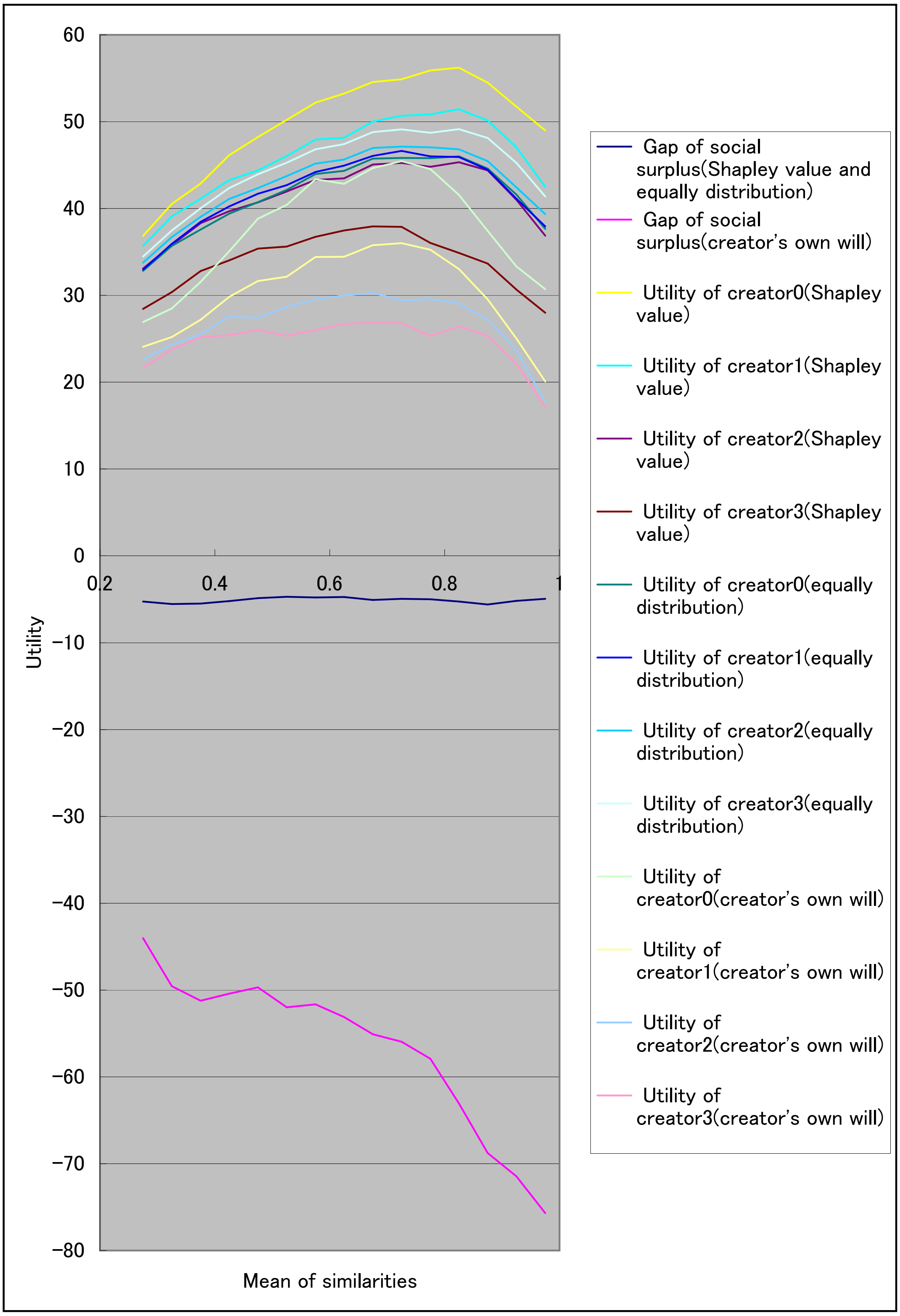

Figure 5: Utility and gap of social surplus of the simulation by 4 creators and 4 services

value (and distributed equally) is less than those in the case based on their own will regardless of creators' similarity. In the case that both of the number of creators and the number of services are three or four, utility of creator c_0 in the case that profit is distributed based on Shapley value is the highest regardless of creators' similarity.

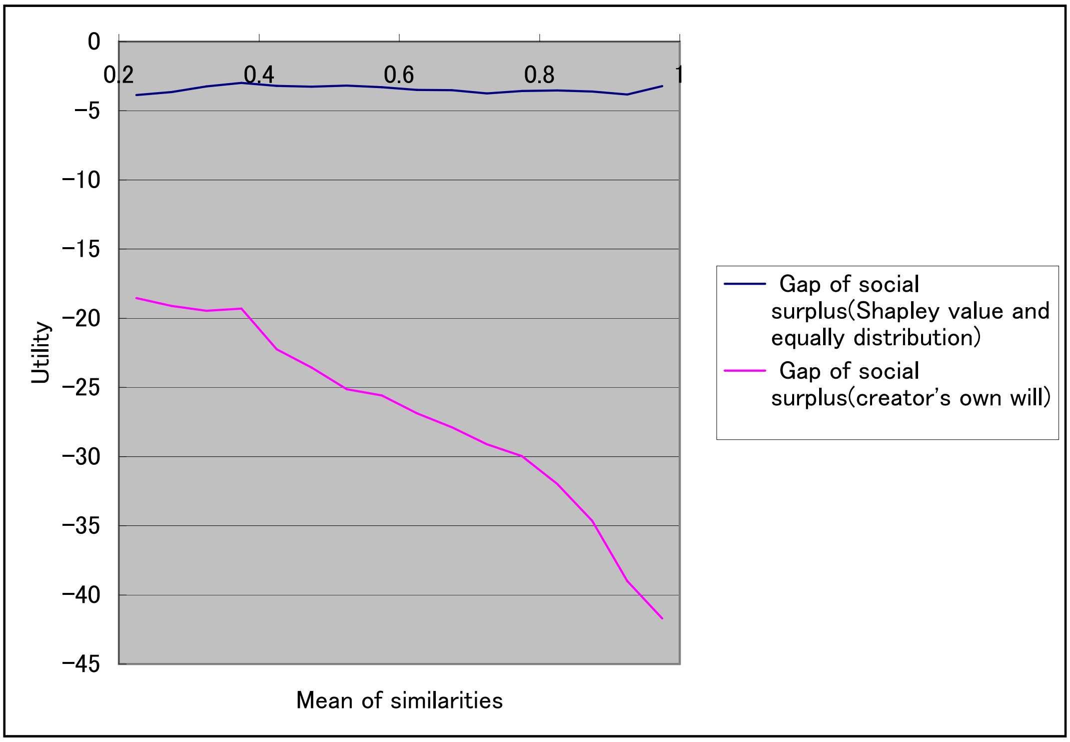

Figure 6: Gap of social surplus of the simulation by 3 creators and 3 services

We pick up gap between ideal social surplus and actual social surplus which is determined by the results of simulations actually in each way of distribution of profit. Figure 6 shows a gap between social surpluses in the case that both of the number of creators and the number of services are three. Figure 7 shows a gap between social surpluses in the case that both of the number of creators and the number of services are four. In the both cases, absolute value of gap between social surpluses by Shapley value (and distributed equally) is less than that by creators' own will. In short, creators make more variety of services in the case that profit is distributed based on Shapley value (and distributed

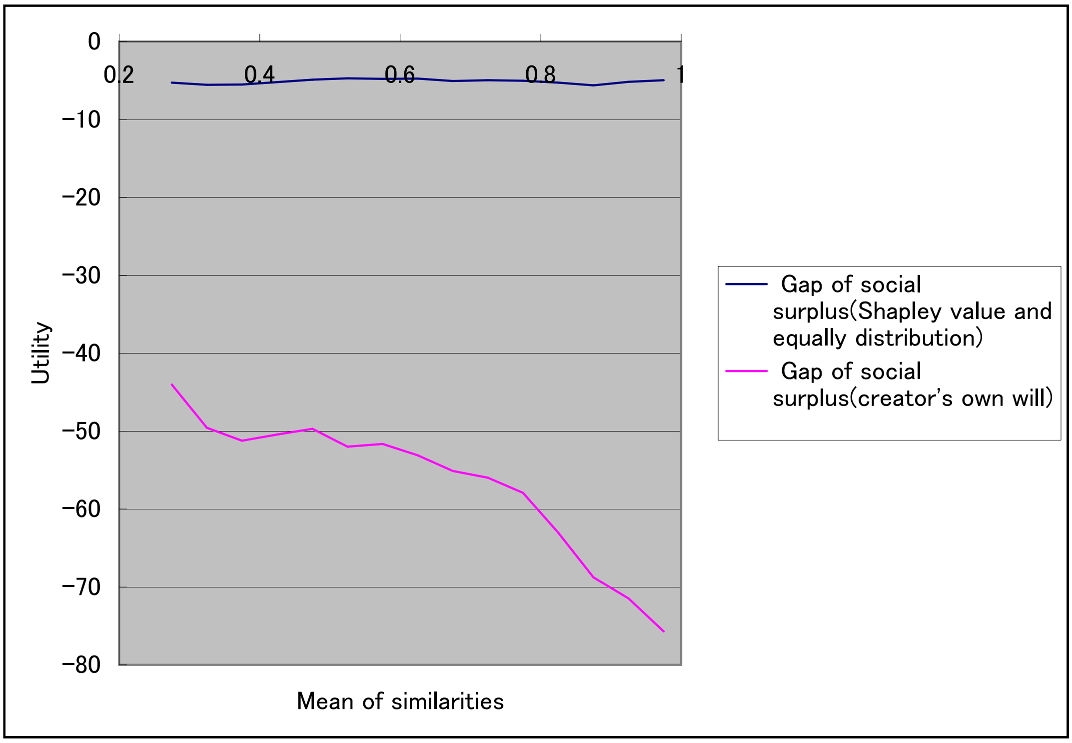

Figure 7: Gap of social surplus of the simulation by 4 creators and 4 services

equally).

As both of the number of creators and the number of services increase from two to four, gap between social surpluses in the case that creators choose services based on their own will and gap between social surpluses in the case that profit is distributed based on Shapley value (and distributed equally) becomes bigger. In the case that creators choose services based on their own will, they concentrate on much profitable services. As the number of services increase, absolute value of gap between ideal social surplus and actual social surplus in the results of simulations become bigger because the number of the services which creators do not make increase. On the other hand, in the case that profit is distributed based on Shapley value (and distributed equally), absolute value of gap between ideal social surplus and actual social surplus in simulations does not drastically increase same as in the case by their own will. This is because creators surely form total coalition and make all services, social surplus does not drastically decrease in the case of Shapley value (and distributed equally).

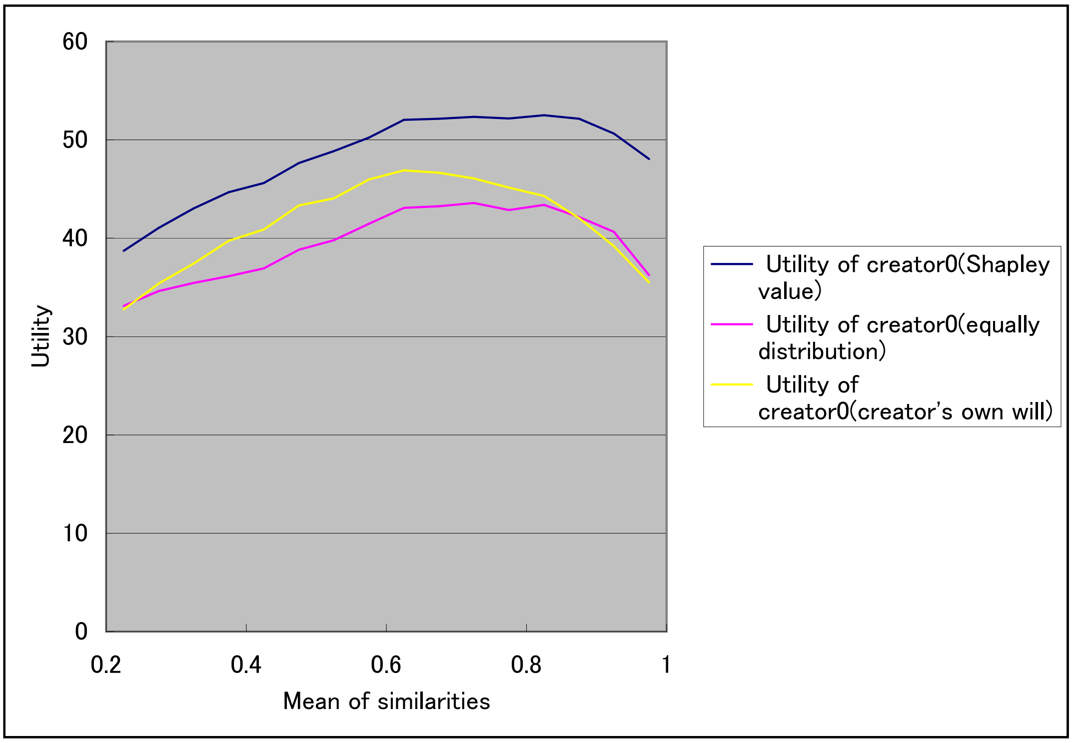

Figure 8: Utility of creator0 of the simulation by 3 creators and 3 services

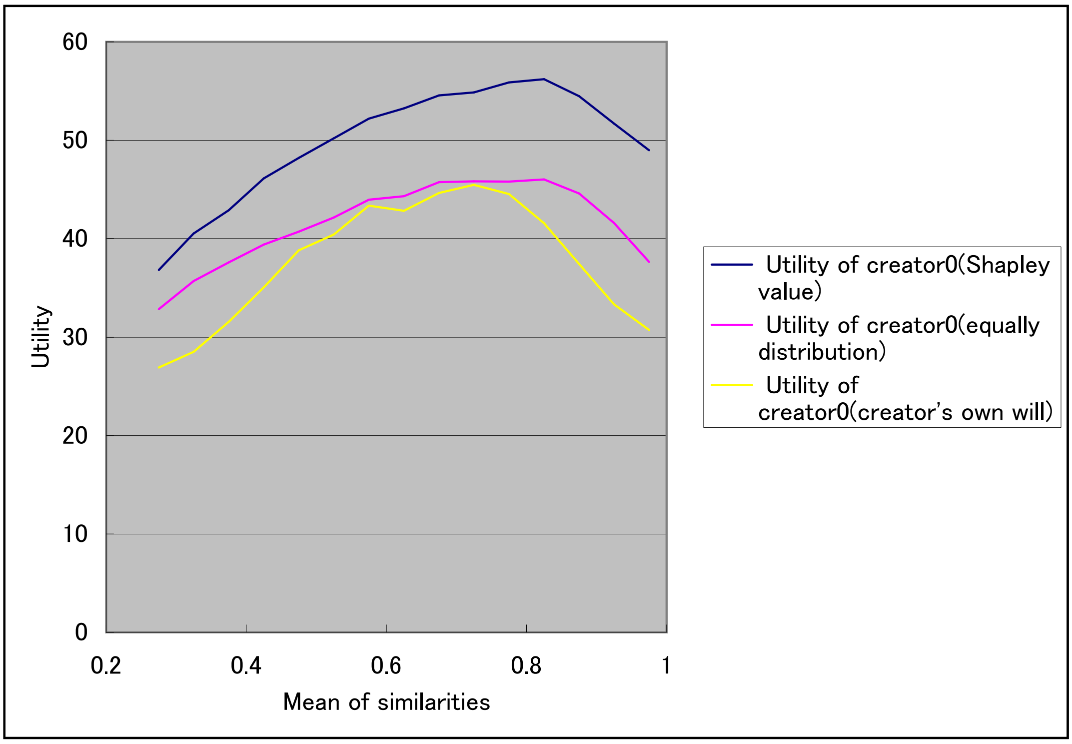

Figure 9: Utility of creator0 of the simulation by 4 creators and 4 services

We pick up utility of creator c_0, who is the most competent in each way of distribution, in the case that both of the number of creators and the number of services are three and four. Figure 8 shows just utility of creator c_0 in the case that both of the number of creators and the number of services are three. Figure 9 shows just utility of creator c_0 in the case that both of the number of creators and the number of services are four. Both of the results show that utility of creator c_0 by Shapley value is higher than that by their own will and than those by distributed equally. The defect does not happen that utility of creator c_0 by their own will is higher than those by Shapley value like the case that both of the number of creators and the number of services are two. If the number of services increase, it becomes unlikely to happen that creators make all services on condition that similarities between creators are low. As a result, total profit which creators obtain decreases and profit of each creator decreases. Even in the case that creators are dissimilar, creator c_0 can get more profit even though he/she transfer profit to other creators by making total coalition by distributing profit based on Shapley value because of avoiding creation of same services which creators make if they choose services based on their own will.

Chapter 7 Designing a Way to Select a Profit Sharing Method

The following is the design of a way to select methods of distribution of profit and to make a group of creators in order to combine the preference of creators with the demand of users based on above-mentioned discussions and results of simulations.

Results of simulations indicate that social surplus by Shapley value is always higher than that of creators' own free will or equally distribution. But utility of creators by Shapley value are not consistently the most highest. In the case that the number of creators and services is 2 and similarity is low, the most competent creator's utility by Shapley value is lower than that by creators' own free will. To prevent he/she from withdrawing, it is impossible to apply Shapley value to the method of distribution of profit.

We show the way how to apply Shapley value to the distribution of profit based on above-mentioned discussions and results of simulations. In the case that the number of creators and services is more than three, social surplus increase. And in this case, the most capable creator continues to join total coalition because utility of him/her by Shapley value is higher than that by others. In the case that the number of creators and services is two, because the utility of him/her by Shapley value is lower than that by creators' own free will, he/she does not cooperate with formation of total coalition. But social surplus by creators' own free will is lower than that by Shapley value. And a variety of services are not produced.

To avoid this defect, it is good to group creators who are high similarities or to make a group of which the number is more than three.

It is possible to apply Shapley value by grouping creators who are high similarities by taking account of services created by each creator in the past and so on. In making a group, it is good to group creators who are not high similarities but high similarities. It is preferable to group creators who are as high similarities as possible by guessing creator's preference and ability from taking into consideration of the history which each creator created in the past and their popularity and so on.

If it is impossible to group creators who are high similarities, it is possible to apply Shapley value by making groups of which the number is more than three not two. It is thought that the number of creators is a few and the number of services requested by users is many. So it is impossible to gather the enough number of creators or the history to do the above mentioned way. In this case it is necessary to group creators of which the number is not two but is more than three by adding more than one creator.

Chapter 8 Conclusion

This research aims to create a variety of services by distributing the profit which is obtained from services according to Shapley value. By the definition of characteristic function cfv, this research enables us to transform the distribution of profit into a game in coalitional form with transferable utility, so can apply Shapley value. This research made sure the case to which Shapley value can apply and to which it can not apply by simulations. This research showed a guideline how to distribute the profit and how to make creators' group.

It is necessary to transform the problem of distribution of profit into a game in coalitional form with transferable utility in order to distribute profit which is obtained from services based on Shapley value because Shapley value is the way to calculate the profit of each player in a game in coalitional form with transferable utility (C, cfv) . This research tried to transform the problem into a game in coalitional form with transferable utility by defining super-additive characteristic function cfv, the value of which is the profit of each coalition which is consisted of creators. This research defined characteristic function cfv on the ground of total profit from services to make which is presumed to be common information and services which each creator has ability to make.

If creators are dissimilar, creators make a variety of services and to get much utility even based on creators' own free will because the services which creators want to make are different. In this case, if profit of each creator is distributed according to Shapley value, capable creators have to transfer profit though they make different services without transfer. It invites that competent creators who have to transfer their profit withdraw from the distribution which use Shapley value and that they choose the way based on their own free will. If creators decide the service based on their own free will, they concentrate on some services and do not make a variety of services. So it decreases social surplus. It is necessary to compare and examine which way is good in each case. This research worked on simulation of the case that creators decide the service to make based on their free will, the case that they decide the service to make according to Shapley value and the case that creators distribute profit equally. We researched the relationship between similarity of creators and creators' utility and between similarity of creators and social surplus.

This research considered which way increases creators' utility and social surplus actually and designed the way to support selection of methods distributing profit and to make group.

This research tries to use methods sharing profit as situation demands and achieved the following contributions.

Scope of Applying Shapley Value This research showed changes of creators' utility and social surplus as similarity of creators changes in the case of the way that distribution are based on creators' free will, in the case of the way that distribution are based on Shapley value and in the case of the way that profit is distributed equally. If the number of creators is two and they are dissimilar, the profit of competent creators in the case decisions are made based on creators' free will outweighs their profit in the case of the way that distribution are made based on Shapley value. In this case, application of Shapley value cause the problem that competent creators have dissatisfaction and withdraw from this way. Hence this case is inapplicable to use Shapley value.

Designing a Method to Share Profit and to Make a Group In the case that similar creators make a group they can make a variety of services and increase social surplus thanks to the application of Shapley value. More than three creators make a group even if similar creators can not take part in same group by considering their creation career or something else, they can make a variety of services and increase social surplus by application of Shapley value.

This research shows what case is useful for application of Shapley value and designs the way to select of methods of profit's distribution and to make group.

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Appendix: Results of Simulations

As an appendix we show datum which are the results of simulations done in Chapter 6 and which are not included in the body. Figure A.1 shows the variance of means of similarities between creators in the case that the number of creators and services is 3. Figure A.2 shows the variance of means of similarities between creators in the case that the number of creators and services is 4.

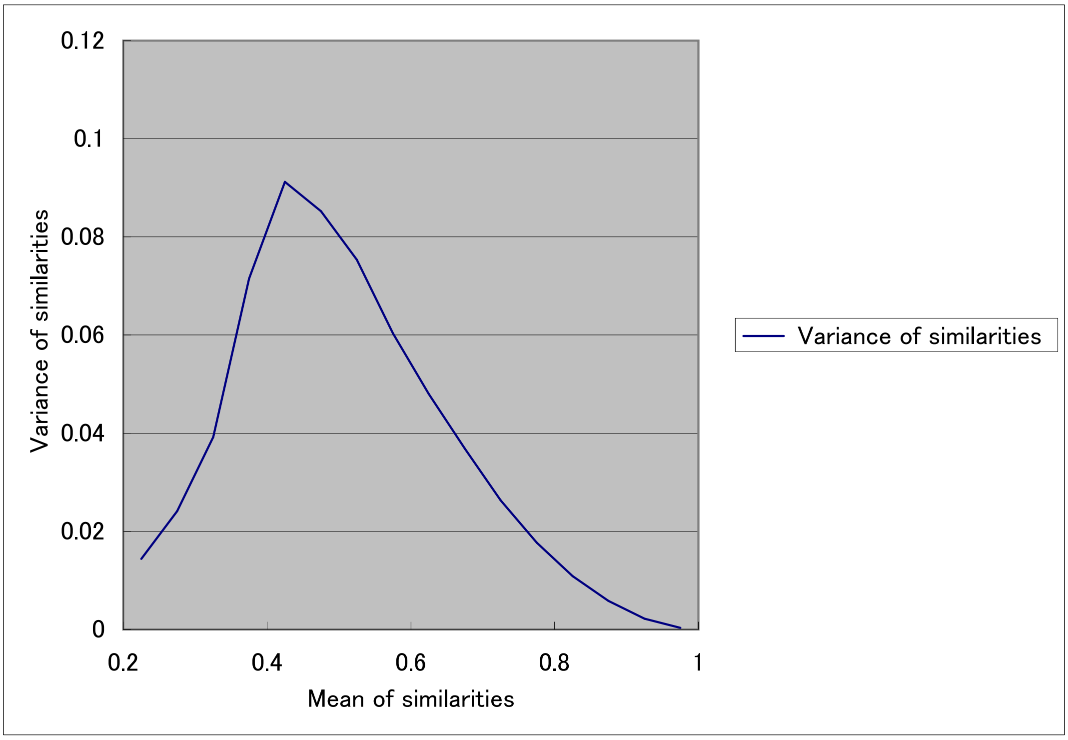

Figure A.1: Variance of similarities of the simulation by 3 creators and 3 services

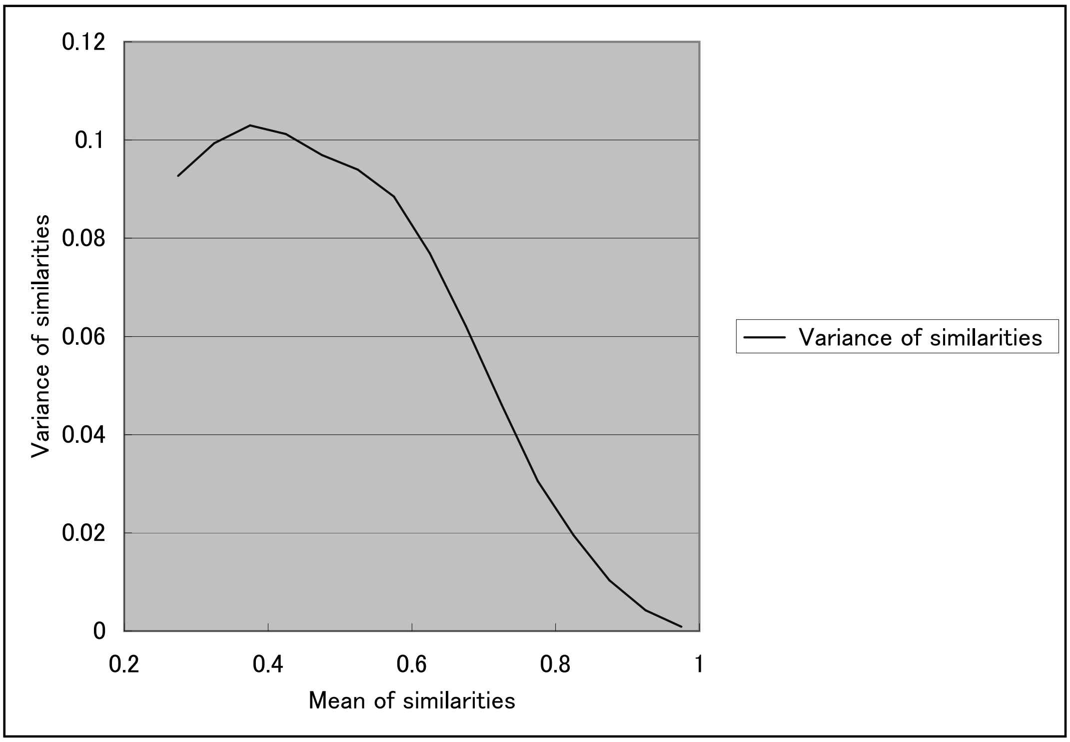

Figure A.2: Variance of similarities of the simulation by 4 creators and 4 services