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Selection of Optimum Successive State Based on Cloud Model in Simulation Reasoning of Complex System Using QSIM

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Abstract

As the absence of effective depictive expression of uncertain information effects the effectively selection of optimum state, the selection method of optimum state of qualitative modeling and reasoning process in complex system based on QSIM and cloud model is proposed. Firstly the calculation method of similarity degree using the distance based on cloud model is given. Then the selection methods of optimum state of qualitative modeling using similarity degree based on cloud model are studied. The selection method of optimum state using the distance based on cloud model is used in constraint filter. Lastly the proposed method is applied to the case of modeling in the agile supply chain management for verifying the proposed methods. The methods proposed in this paper have the merit of objective expression the uncertain information. And the fusion of qualitative and quantitative information can be used in complex system simulation

Keywords: *complex system, qualitative modeling, simulation reasoning, QSIM, selection of optimum state*

1. Introduction

The method of modeling and simulation reasoning for the research on complex system is commonly used because the complex system is lack of sufficient information. The information in complex system is fuzzy, random and uncertain. The qualitative simulation method called QSIM can simulate the behavior and state of complex system provided with the qualitative information. So simulation method based QSIM is often used as the best method to analyze the complex system. QSIM method is firstly proposed by Kuipers in 1986 [1]. In QSIM the qualitative differential equation of system firstly is created. The qualitative differential equation of system is composed of algebra constraint, monotonous constraint and differential constraint. Then according to the qualitative differential equation of system the reasoning of system simulation is executed from the current state. The successive state is selected form the state space. The inconsistent state is filtered by the constraint filter, time-sequence filter and global filter which are called as the filter technology in QSIM [1]. Since the emergence of QSIM, it has been using in various fields including computer science, information science and management science and so on [2-6]. In QSIM the selection of optimum successive state in simulation reasoning of complex system is the key research content which is the basement of filter technology. In existent research literatures the selection of optimum successive state for QSIM has three main methods. Firstly the selection of optimum successive state for QSIM based on distance number is proposed in literature [7] in which the selection of optimum successive state based on calculation of distance number is

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given. The method of selection of optimum successive state based on distance number has the character of subjective and dependent on the calculation of distance. Secondly The representation method of qualitative language based on fuzzy mathematics has been applied in intelligent control [8]. The selection of optimum successive state for QSIM based on fuzzy number and fuzzy theory is proposed in literature [9-11] in which the selection of optimum successive state based on calculation of fuzzy distance is given. The state space and state transfer are expressed by fuzzy distance. The method of selection of optimum successive state based on fuzzy number has the character of using the uncertain information based on fuzzy method. But this method may filter the states which are required by the system. Thirdly the selection of optimum successive state for QSIM based on grey number and grey theory is proposed in literature [12-14] in which the selection of optimum successive state based on calculation of grey number is given. The state space and state transfer are expressed by grey distance method. The method of selection of optimum successive state based on grey number has the character of using the uncertain information based on grey method. But this method is only used in the situation of poor information. In the existent three main methods, the method based on distance number has the following shortcomings: 1) difficult to ascertain the scope and boundary of uncertain information. So the method may bring many inconformity states. 2) When the distance is large the precision of simulation may be lower [15]. The method based on fuzzy number has the following shortcomings: 1) Difficult to find the suitable method of ascertaining the fuzzy parameter and dividing method for fuzzy space. 2) Difficult to ascertain the mapping between the true value and fuzzy value. So it is difficult to ascertain parameter value of fuzzy of simulation system. 3) That the ladder-shaped fuzzy number commonly is used to express the uncertain information can bring the many inconsistent states [16]. The method of grey number theory has the limitation of only using in the situation of poor information.

For the existent problems, in this paper the method of selection of optimum successive state based on cloud model in complex system simulation is proposed. In this method the distance is calculated by the similarity of cloud models. This method inherits the merit of cloud model which is objective method expressing the fuzzy and random of uncertain information. In 1995 the cloud model and relative theory are proposed by Li Deyi who is the academician in Chinese science institution [17]. In the following, the Section 2 gives the expression of state space, state representation and state transfer based on cloud model. Section 3 gives the method of selection of optimum successive state based on cloud model in complex system simulation. Section 4 gives the application case of method of selection of optimum successive state based on cloud model in supply chain. Section 5 gives the conclusions and the future works.

2. Representation of State Space, State Representation and State Transfer based on Cloud Model

The normal distribution is commonly suitable for all situations. The normal cloud model represented as C（Ex, En, He）is used to represent the uncertain information in complex information simulation. Ex, En, He are called respectively expectation, entropy and super-entropy of the model. This model can represent the parameter space using the transfer bridge between the qualitative information and quantitative information. This brings the best method for using simultaneously the qualitative information and quantitative information. Supposing U is the region $U=\{x\}$. T is the language value related with U. The membership degree of x in U for T is a random number which has the stable tendency [18]. The distribution of membership degree in the region is called the cloud model. The value $U(x) = L(x)$ is between 0 and 1. The cloud is the mapping from U to [0, 1]. $U(x) = L(x) : U \to [0,1]\ \forall x \in U, x \to L(x)$.

The mathematic expectation curve of normal cloud model is the following [16, 17]:

$$f_1(x) = e^{-\frac{(x-Ex)^2}{2En^2}} \quad \mathbf{(1)}$$

Then the normal cloud model is used to create the representation space of system variable. The hint figure is shown in Figure 1 in which the representation space of one of system variable is created. There are 9 qualitative language variable in Figure 1. The qualitative variable space can be created by cloud model transfer based on history data or group decision. The detailed cloud transfer method can be seen in literature [18, 19]. The adjacent values are the soft-division in qualitative space Q_c. The adjacent value of soft-division can fully express the uncertainty of system information. All states of system variables are represented by cloud model. The current state of system is composed of all current states of system variables.

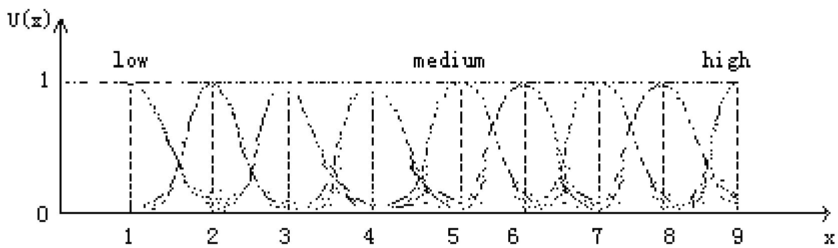

Figure 1. The hint of representation space of one of system variable

The state space system using the cloud model represents binary state combinations (A, B) to represent, A and B are expressed using the normal cloud model. If the cloud entropy and hyper entropy is 0, then its value is quantitative, not qualitative values. A and B values derived from the qualitative space Q_c.

The state transfer of system variable is defined as following four kinds of transfers[20]:

1) N transfer: the value of system variables is constant and the value of the system variable conversion rate is also unchanged.

2) M transfer: the value of system variables is not constant and the value of the system variable conversion rate is unchanged.

3) R transfer: the value of system variables is constant, the value of the system variable conversion rate is changed.

4) MR transfer: the value of system variables is not constant, the value of the system variable conversion rate is also changed.

System variable caused the system state transition. State transitions of one or more variables at a time from one state to another state thus the system state is changed. The state of the system at a time is the combinations of system state variables. Optimal state is the state variable meets the system constraints. In Section 3 the calculation method of arrival time between two adjacent states is given.

3. Selection of Optimum Successive State based on Cloud Model

3.1. Calculation method of similarity degree of two cloud models

In the following the calculation method of similarity degree of two cloud models is given. The method is proposed by the author of this research. That paper on the calculation method has been published by the international journal of digital content technology and its applicant. The detailed calculation method will be seen in that article [21]. The area of every part in Figure 2 (see [21]) is viewed as the area of ladder-shaped whose high is the average distance, whose top-side and bottom-side is the approximate length of left and right sides mathematic expectation curve of normal cloud model. The area of every part in Figure 2 and the approximate length of left and right sides mathematic expectation curve of normal cloud model can be calculated by the above formula and method. Then the average distance D between two adjacent cloud models can be calculated by the area formula of ladder-shaped. The brief content of calculation method is given in the following [21]:

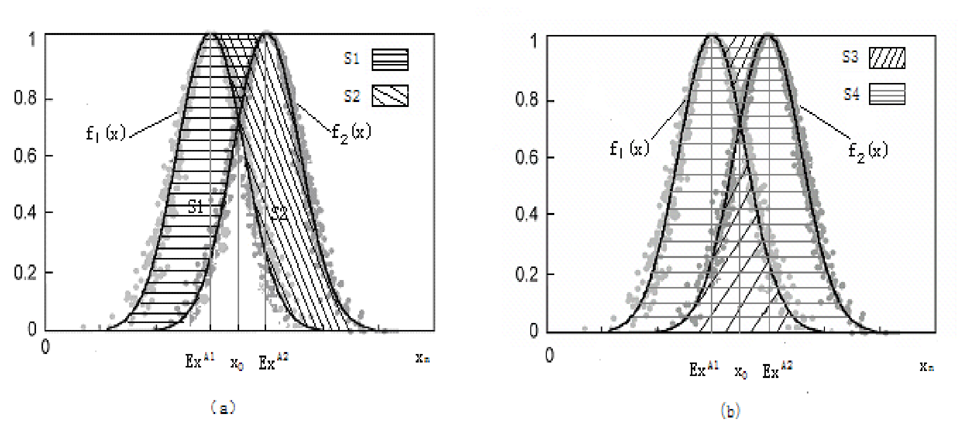

Figure 2. The hint figure of cloud model of adjacent state

Supposing the qualitative value of adjacent state is A1, A2. The number character cloud model of A1,A2 is respectively $C^{A1}(Ex^{A1}, En^{A1}, He^{A1})$ and $C^{A2}(Ex^{A2}, En^{A2}, He^{A2})$. The hint figure of cloud model of A1,A2 is shown in Figure 3. In Figure 3 curve f1(x) is the mathematic expectation curve of cloud model $C^{A1}(Ex^{A1}, En^{A1}, He^{A1})$ of qualitative value of state A1. The curve f2(x) is the mathematic expectation curve of cloud model $C^{A2}(Ex^{A2}, En^{A2}, He^{A2})$ of qualitative value of state A2. The point of intersection of f1(x) and f2(x) is x_0. The calculation formulas of area in Figure 3 are in the following [21]:

$$S1 = (Ex^{A2} - (-x_n)) * 1 - \int_{Ex^{A2}-3En}^{Ex^{A2}} f_2(x)dx) - (Ex^{A1} - (-x_n)) * 1 - \int_{Ex^{a1}-3En}^{Ex^{A1}} f_1(x)dx) \qquad \textbf{(2)}$$

$$S2 = ((x_n - Ex^{A1}) * 1 - \int_{Ex^{A1}}^{Ex^{A1}+3En^{A1}} f_1(x)dx) - ((x_n - Ex^{A2}) * 1 - \int_{Ex^{A2}}^{Ex^{A2}+3En^{A2}} f_2(x)dx) \qquad \textbf{(3)}$$

$$S3 = \int_{Ex^{A2}-3En^{A2}}^{x_0} f_2(x)dx + \int_{x_0}^{Ex^{A1}+3En^{A1}} f_1(x)dx + \int_{Ex^{A1}}^{x_0} (1 - f_1(x))dx + \int_{x_0}^{Ex^{A2}} (1 - f_2(x))dx \qquad \textbf{(4)}$$

$$S4=\int_{Ex^{A1}-3En^{A1}}^{Ex^{A1}+3En^{A1}} f_1(x)dx+(x_n-Ex^{A1})*1-\int_{Ex^{A1}}^{Ex^{A1}+3En^{A1}} f_1(x)dx)-((x_n-Ex^{A2})*1-\int_{Ex^{A2}}^{Ex^{A2}+3En^{A2}} f_2(x)dx) \quad \textbf{(5)}$$

The length of left and right sides of cloud model are calculated by the following tiny step length method [21]:

（1）Supposing $f_n(x)=e^{-\frac{(x-Ex)^2}{2En^2}}$. Respectively assuming the distances [Ex-3En, Ex], [Ex ,Ex+3En].

（2）In the distances [Ex-3En, Ex],[Ex ,Ex+3En],supposing the current point $x_{current}=x_{current}+\Delta x$.In the first time assumes the left point of distance（x_{left}, y_{left}）,and $x_{current}=x_{left}$.

（3）In the distances [Ex-3En, Ex],[Ex ,Ex+3En], $x_{current}$ is viewed as the start point, supposing x step by step increasing by the tiny step length Δx. So x= $x_{current}+\Delta x$, calculating $\Delta y=f_n(x_{current}+\Delta x)-f_n(x_{left})$.

In the first time $x=$ x_{left} + Δx, calculating $f_n(x)$ = $f_n(x_{left}+\Delta x)$, currently $\Delta y=f_n(x_{left}+\Delta x)-f_n(x_{left})$. In the latter times the situation is same to the first time.

（4）Calculating $L_{\Delta x}=\sqrt{(\Delta x)^2+(\Delta y)^2}$,calculating $L=L+L_{\Delta x}$

（5）Looping to execute（2）-（4）, until $x_{current}+\Delta x$ is greater than the value of right point of distance.

（6）Currently L is the approximate length of left and right sides mathematic expectation curve of normal cloud model .Distance of L_{left} is [0, Ex]）,and distance of L_{right} is [Ex , x_n]）.

Supposing the similarity degree between two cloud model is S: S（A1,A2）$=\frac{1}{D}$.

3.2. Selection of optimum successive state based on similarity degree of cloud model

The constraint equation based on cloud model and spaces of value of variable are used to solve the algebra constraint, differential constraint and monotonous constraint. The value of constraint variable can be solved by this constraint equation. This process will use the algebra operation, differential operation and monotonous operation based on cloud model. The value of constraint variable can be solved. But the value is maybe out of space of value of variable. This can be solved by the method based on similarity degree of cloud model to calculate which value is approximate the value of constraint variable in space of value of variable. The value is approximate with the value of constraint variable in the space of value of variable which is viewed as the value of constraint variable. The current corresponding state is viewed as the successive state of constraint variable. The state is called as the optimum successive state. The algebra constraint, differential constraint and monotonous constraint based on cloud model is given in the following:

（1）Algebra constraint

For the addition operation and subtraction operation $A_1(Ex_1, En_1, He_1) \pm A_2(Ex_2, En_2, He_2) = A(Ex, En, He)$: formula $Ex = Ex_1 + Ex_2$ （addition operation）or $Ex = Ex_1 - Ex_2$ （subtraction operation）, $En = \sqrt{En_1^2 + En_2^2}$, $He = \sqrt{He_1^2 + He_2^2}$ is used to calculate the numeral character value of constraint variable[22].

For the multiplication operation and division operation $A_1(Ex_1, En_1, He_1) * / \div A_2(Ex_2, En_2, He_2) = A(Ex, En, He)$: formula $Ex = Ex_1 Ex_2$ （multiplication operation） or $Ex = Ex_1 / Ex_2$ （ division operation ）, $En = Ex_1 Ex_2 \sqrt{\left(\frac{En_1}{Ex_1}\right)^2 + \left(\frac{En_2}{Ex_2}\right)^2}$, $He = Ex_1 Ex_2 \sqrt{\left(\frac{He_1}{Ex_1}\right)^2 + \left(\frac{He_2}{Ex_2}\right)^2}$ is used to calculate the numeral character value of constraint variable [22].

When the result of algebra operation is not in the space of value of variables of system similarity degree between the calculated numeral character values of constraint variable $A(Ex, En, He)$ with the cloud model $B(Ex, En, He)$ in the space of value of variable should be calculated. The relative method is given in Section 3.1. Supposing ε is threshold value, if

$$S(A, B) > \varepsilon \tag{6}$$

Then the cloud model $B(Ex, En, He)$ in the space of value of variable can be used to replace the cloud model $A(Ex, En, He)$ as the operation result. If three are many models in the space of value of variable satisfied the formula (6) then the cloud model with minimum similarity degree is selected.

The following example illustrates the use of algebraic constraint to select the optimum successive states. For algebra constraint $X + Y = Z$. The current values of X , Y are $A_1(Ex_1, En_1, He_1)$ and $A_2(Ex_2, En_2, He_2)$. According to above method the current values of Z can be calculated as $A(Ex, En, He)$. But the $A(Ex, En, He)$ is not certainly in the space of value of variable. If $A(Ex, En, He)$ is in the space of value of variable then the $A(Ex, En, He)$ maybe is the optimum successive state for Z combined with other constraints. If not the formula (6) can be used to select the optimum successive state from the space of value of variable.

（2）Differential constraint

The differential constraint is the key constraint to ascertain the behavior of system. Supposing the value of system variable and the variable ratio of value of system variable in differential constraint are all represented by cloud model. The differential constraint is represented as the following formula [22]:

X(t)=deriv Y(t) (7)

In the above formula, the value of X（t）, Y（t） all come from the space of qualitative value of system variable. The formula implies that the qualitative value of X（t）and the variable ratio of Y（t）is consistent.

If the qualitative value of X（t） is recorded as（A_x, B_x）, the variable ratio of Y（t） is recorded as（A_y, B_Y）and if differential constraint X(t)=deriv Y(t) is right, then $A_x = B_y$.

If in the process of system simulation, in current state for the space of value of system variable, $A_x = B_y$ is not satisfied. Then supposing ε is threshold value, when A_x, B_y satisfy the following formula:

$$S（A_x, B_y）> \varepsilon$$

Then X,Y called as satisfying the differential constraint X(t)=deriv Y(t) under the similarity degree of ε. Recorded as: $A_x = \varepsilon B_y$.

（3）Monotonous constraint and its judgment

Supposing between the parameter X and Y in the system exists the constraint $M^+(X,Y)$ or $M^-(X,Y)$. And qualitative state of X and Y is（A_1, B_1）and Y（A_2, B_2）, then the regulations of monotonous constraint of $M^+(X,Y)$ or $M^-(X,Y)$ are represented in the following [22]:

$$M^+(X,Y) = \begin{cases} if\ B_1 = 0 & then & B_2 = 0 \\ if\ B_1 > 0 & then & B_2 > 0 \\ if\ B_1 < 0 & then & B_2 < 0 \end{cases} \qquad M^-(X,Y) = \begin{cases} if\ B_1 = 0 & then & B_2 = 0 \\ if\ B_1 > 0 & then & B_2 < 0 \\ if\ B_1 < 0 & then & B_2 > 0 \end{cases} \qquad \textbf{(8a,b)}$$

So the key problem is to judge whether the value of B_1 is zero, value of B_1>0 or value of B_1<0. The qualitative value of B_1 is represented by three numeral characters of cloud model. So it is required to judge the relation between B_1 and 0. The relation between B_1 and 0 probably exists three cases which are shown in Figure 3. In Figure 4 for the relation in the case 1 and case 2, the relation between the cloud model of B_1 and 0 does not exist the obvious = ,< or > contrast. The reason is that the “Ex of B_1”>0 is not the full condition to judge the B_1>0 according to the theory of cloud model .

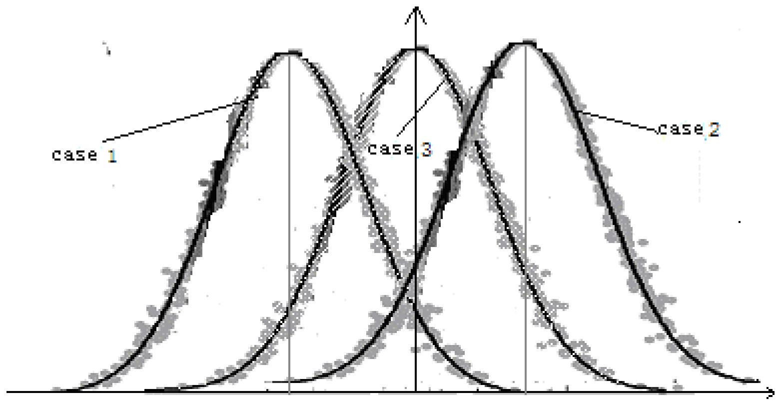

Figure 3. The hint of relation between B1 and 0

Currently it is required to calculate the similarity degree S（B1,0）between B_1 and 0,if S（$B1,0$）$>\varepsilon$（supposing ε is threshold value）, then reviewed as $B_1 = 0$. If S（$B1,0$）$<\varepsilon$,and $Ex^{B1} > 0$,then reviewed as $B_1 > 0$. If S（$B1,0$）$<\varepsilon$, and $Ex^{B1} < 0$,then reviewed as $B_1 < 0$. The calculation method of similarity degree can be seen in section 3.1. When calculating 0 is viewed as the cloud model whose numeral character is (0,0,0).

Using the same principle when executing the reasoning of regulation of simulation, it is required to judge the relation between successive state of B_2 and 0, then to select the successive state of B_2. Firstly selecting anyone possible successive state from all possible successive states set, then to calculate the similarity degree S（B2,0）between the possible successive state B_2 and 0. If S（$B2,0$）$>\varepsilon$（supposing ε is threshold value）, then reviewed as $B_2 = 0$. If S（$B2,0$）$<\varepsilon$,and $Ex^{B2} > 0$,then reviewed as $B_2 > 0$. If S（$B2,0$）$<\varepsilon$,and $Ex^{B2} < 0$,then reviewed as $B_2 < 0$. Then decision is made on whether the selected successive state should be added or deleted from all possible successive states according to reasoning regulation of selected state.

4. The Case of Selection of Optimum Successive State in the System Simulation of Agile Supply Chain

4.1. Basic situation of application case of agile supply chain

Three is a case of selection of optimum successive state in the system simulation of agile supply chain. Three are three roles including about manufacturer, seller and supplier on one kind of production on one industry. The production ability of raw material of supplier is P1. The production quantity of raw material of supplier is Q1. The production cycle of raw material of supplier is T1. The production ability of manufacturer is P2. The production quantity of manufacturer is Q2. The production cycle of manufacturer is T2. The production quantity of manufacturer in warehouse is Q21. The quantity of raw material of manufacturer in warehouse is Q22. Supposing producing one unit production requires one unit raw material. The requirement ability of seller is P3. The requirement cycle of seller is T3. The requirement quantity of seller is Q3. Because of the dynamic variation of situation, the variables including future production ability and production cycle etc all are the uncertain value which is represented by the cloud model. The system modeling among manufacturer, seller and supplier is created in the following. Firstly the algebra constraint is created in the following:

T3 > =T2 **(9)**

T2< = (Q3-Q21)/P2 **(10)**

(Q3-Q21-Q22)/P1 > = T1 **(11)**

Secondly the differential constraint between production quantity of raw material of supplier Q1（t）, production ability of raw material P1 and the differential constraint between production quantity of manufacturer Q2(t), production ability of manufacturer P2 are created in the following:

P1=dQ1(t)/dt **(12)**

P2=dQ2(t)/dt **(13)**

Thirdly the representation of cloud model of qualitative space of production quantity (warehouse quantity, requirement quantity etc use the same qualitative space) and cycle (production cycle, required supply cycle etc use the same qualitative space) is created. The qualitative space of production quantity is ascertained as{very high, high, medium, low, very low},in the space very high, high, medium, low and very low are respectively represented by the cloud model C11（5000,500,40）,C12（1000,200,30）,C13（300,48,8）,C14（100,28,4） and C15（0,18,3）. The qualitative space of cycle is ascertained as {very long, long, medium, short, very short},in the space very long, long, medium, short and very short are respectively represented by the cloud model C21（90,18,3）,C22（60,12,2）,C23（30,7,1）,C24（10,3,0.5）,C25（0,2,0.3）.Using the same principle, the qualitative space of production ability is ascertained as{very high, high, medium, low, very low},in the space very high, high, medium, low and very low are respectively represented by the cloud model C31（300,30,4）,C32（100,20,3）,C33（30,5,1）,C34（10,3,0.5）,C35（0,2,0.5）. The hint figures of space of corresponding cloud model are shown in Figure 4.

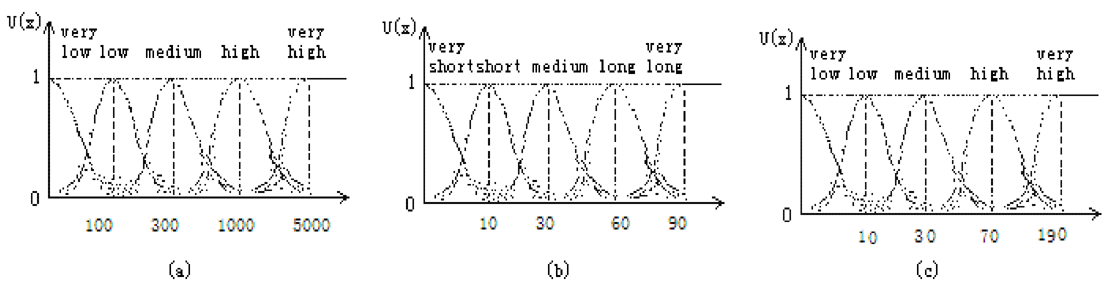

Figure 4. Hint of qualitative space of production quantity, cycle and production ability

The qualitative space of variation ratio of production quantity is ascertained as{very fast, fast, medium, slow, very slow} which is shown in Figure 5. In Figure 6 the direction of negative coordinate represents the inverse variation direction. In the space very fast, fast, medium, slow and very slow are respectively represented by the cloud model C41(190,20,4), C42(70,15,2), C43(30,5,1), C44(10,3,0.5), C45(0,2,0.3). Each axis direction is qualitatively negative value indicates the rate of change in the opposite direction, and have the same value in the positive direction. In order to simplify the process, supposing variation ratio of cycle, variation ratio of production and variation ratio of production ability use the same qualitative space of variation ratio. In fact the same case is impossible, but it is no influence on this case in this paper.

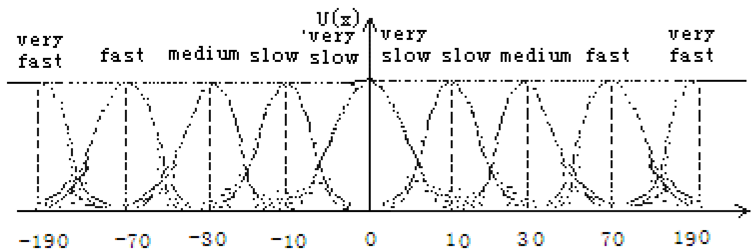

Figure 5. The qualitative space of variation ratio of production quantity

4.2. Calculation example of optimum successive state in the case of agile supply chain

In the following the process of constraint filter using similarity degree of cloud model to execute the selection of optimum successive state is shown:

（1）Selection of optimum successive state using similarity degree of cloud model in algebra constraint

Supposing the next state is in the time of supplying production, the constraint of next state is Q3-Q21= Q2.

Supposing the initial state of requirement quantity Q3 is（low, fast）whose cloud model is（C14（100,28,4）,C42(70,15,2)）in the qualitative space. Next possible state of Q3 is（medium, fast）,this sate in the qualitative space is represented as C13（300,48,8）.

Supposing the initial state of quantity in warehouse of manufacturer Q21 is（low, fast）, its' cloud model is（C14（100,28,4）, C42(70,15,2)） in the qualitative space. Then next possible state of Q21 is（low, fast）,this sate in the qualitative space is represent as C14（100,28,4）.

Supposing the current state of production quantity of manufacturer Q2 is（low, very high）, its' cloud model is C14（100,28,4）,C41(190,20,4)）. Next possible state of Q2 is in the following:

N transfer: Next possible state of Q2（low, very high）

M transfer: Next possible state of Q2（medium, very high）

R transfer: Next possible state of Q2（low, very low）,（low, low）,（low, medium）or（low, high）

MR transfer: Next possible state of Q2（medium, very low）,（medium, low）,（medium, medium）or（medium, high）

Firstly using the algebra operation to calculate the value of (Q3-Q21),the result is（200,55,5）,to find the same cloud model with （200,55,5）from the qualitative space of production quantity. Thus loud model is not existent, then selecting the cloud model which “the similarity degree with （200,55,5）”>ε（supposing ε is threshold value）from the qualitative space of production quantity. This state which selected cloud model represents is viewed as next state of Q3. If the cloud model which “the similarity degree with （200,55,5）”>ε does not exist. Then the current state of system is invalid. When supposing the ε =1, to calculate and get that the cloud model C14（100,28,4） is similar to （200,55,5）. So next state of Q3 is C14-{low}.Looping to execute the above process for other constraints, the lastly result is in the following, next possible state of Q2 is:

R transfer: next possible states is（low, very low），(low, low），(low, medium）or（low, high）.

（2）Selection of optimum successive state using similarity degree of cloud model in differential constraint

For differential constraint, the differential constraint 4 is exemplified: P1=dQ1(t)/dt. Checking the set of all possible next state of P1 and Q, according to P1=dQ1(t)/dt, P1 should be equal to current variation ratio of Q1.

Supposing the initial state of raw material of supplier P1 is（very high, very fast）,its' cloud model is（C11（5000,500,40）,C41(190,20,4)）,the set of all possible next state is in the following:

N transfer: possible next state is（very high, very fast）

R transfer: possible next state is（very high, very slow），(very high, medium），(very high, fast）or（very high, very fast）

Supposing the current state of quantity of raw material of supplier Q1 is（low, very high）, its' cloud model is（C14（100,28,4）,C41(190,20,4)）,the set of all possible next state is in the following:

R transfer: possible next state is（low, very low），(low, low），(low, medium）or（low, high）

MR transfer: possible next state is（medium, very low），(medium, low），(medium, medium）or（medium, high）

Currently, P1 is not equal to current variation ratio of Q1. So getting respectively one value from the set of all possible next state of P1 and from the set of all possible next state Q1 to calculate their similarity degree, When supposing the ε =1, to calculate their similarity degree, P1 is not similar to current variation ratio of Q1. So the set of possible next state is invalid.

（3）Selection of optimum successive state using similarity degree of cloud model in monotonous constraint

Supposing there is the monotonous constraint : M^+ （Q1,Q2） in the supply chain simulation system. And current state of production quantity Q2 is （low, very high）, its' cloud model is C14（100,28,4）,C41(190,20,4)）,the set of all possible next state is in the following:

M transfer: possible next state is（medium, very high）

MR transfer: possible next state is（medium, very low）,（medium, low）,（medium, medium）or（medium, high）

Supposing the current state of quantity of raw material of supplier Q1 is（low, very high）,its' cloud model is（C14（100,28,4）,C41(190,20,4)）,the set of all possible next state is in the following:

R transfer: possible next state is（low, very low）,（low, low）,（low, medium）or（low, high）

MR transfer: possible next state is（medium, very low）,（medium, low）,（medium, medium）or（medium, high）

Calculating the relation between Q2 and 0 using the similarity degree to gain the value of qualitative state:Medium-C13（300,48,8）>0.So according to monotonous constraint regulation: M^+（Q1,Q2）, possible next state of Q2 is（medium, very high）,（medium, very low）,（medium, low）,（medium, medium）or（medium, high）.

c. Experiments of optimum successive states and discussions of results

According to the initial situation in the section Ⅳ.a the experiments of above state selection of QSIM based on cloud model is executed. In this experiment the some additional constraints is added in the process of simulation in the following:

The initial states of T1, T2 and T3 respectively are (short, very slow)=((10,3,0.5),(0,2,0.3)), (short, very slow)= ((10,3,0.5),(0,2,0.3)) and (long, very slow)=((30,7,1),(0,2,0.3)). The initial states of Q1, Q2,Q21, Q22 and Q3 respectively are (low, medium)=((0,18,3),(30,5,1)), (low, fast)=((0,18,3), (190,20,4)), (low, slow) =((0,18,3),(10,3,0.5)) and (low, slow)= ((0,18,3), (10,3,0.5)). The initial states of P1 and P2 respectively are ((10,3,0.5), (10,3,0.5))and ((10,3,0.5), (30,5,1)).

The process of simulation is driven by the requirement of seller. The variation situation and tendency of Q3 is increasing before descending. Its states are (low, slow), (medium, slow), (medium, slow) and (low slow). The results of experiment are shown in Figure 6. The results give one situation in one time simulation because the cloud model is uncertain the results may have some difference which reflects the objective situations. In the Figure 6 state series of the total of quantity of production of supplier, requirement quantity of manufacturer, quantity of selling of seller, ratio of production of supplier and ratio of production of manufacturer are shown.

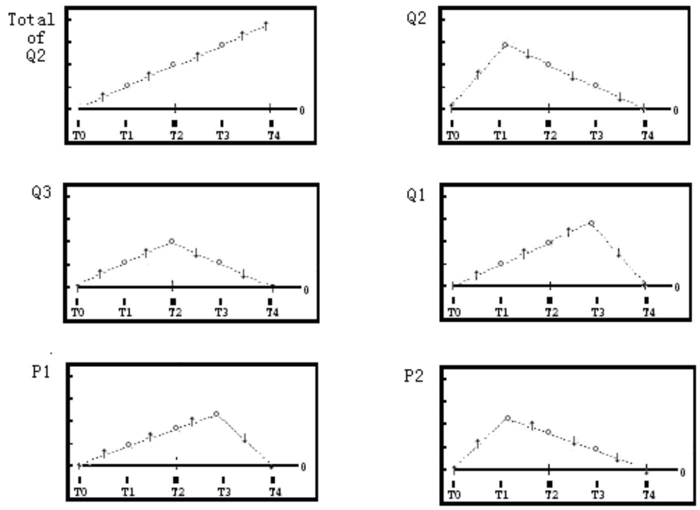

Figure 6. Experiment results of optimum successive in agile supply chain

The state can be induced from the process of simulation using QSIM based on cloud model in the experiments. From the experiment and calculation example the merits of QSIM based on cloud model can be seen in the following:

(1) QSIM based on cloud model can give the multi-value state but the classic QSIM can only the three-value state.

(2) The uncertainty of future situation can be reflected in the experiment by the differences in every time simulation. The reason is that the cloud model is the model that reflects the objective uncertainty in nature and real world.

(3) The more complicate constraint regulations can be added in the process of simulation by the constrain equations. The constraint equations can use similarity degree of cloud model in the process of selection of state.

(4) In the experiment results the sates can be represented by the two-element combination which gives the directions and its value in this direction by the cloud model. But the classic QSIM method can only the direction and can not give the value in the direction.

5. Conclusions

This paper proposes the method of selection of optimum successive state based on cloud model in simulation reasoning of complex system using QSIM. The case of selection of optimum successive state in the system simulation of agile supply chain is given to verify the feasibility and validity of method. This method can inherit the merit of theory and method of cloud model to resolve the problem of uncertain information in complex system simulation using QSIM. Comparing with the relative researches, this method can model the problem suing the cloud model to fully express the uncertainty of information in complex system simulation. The future work is to do the comparison researches with the other method.

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