Abstract

The negotiation goal for High-tech Virtual Enterprise is close relation with participants negotiation behavior, which also is impacted by environment constrict and member enterprise strategies among negotiation process. Multi-Agent negotiation process is formalized described for High-tech Virtual Enterprise and combined programming model for Multi-part and Multi-Issue negotiation and decision are established including of the general programming model and particular programming model, by which united protocol zone and basic negotiation value is ensured from Multi-Agent negotiation power degree, by which united negotiation equilibrium value from Multi-Agent adopting strategies, and finally optimal estate of united utility and equilibrium situation of protocol result are received. The empirical results show Multi-part and Multi-Issue negotiation and decision based on double programming is the important approach for conflict management of High-tech Virtual Enterprise, its acting mechanism is analyzed and operation model is established, which is the effective means for coordinating with collaboration relations among participants, reducing conflict consumption and realizing alliance targets.

Keywords: High-tech Virtual Enterprise, Multi-Agent, Group Negotiation Decision Model, Combined Programming

1. Introduction

According to the violent economic globalization and enterprise competition, high-tech productions have been update rapidly and technology involved has been improved numerous, those make the high and new technology development and application become the key factors of enterprise existing advantages. However, the production R&D activities involve huge investments, long lifecycles and high risk, individual enterprise would be unbearable, and therefore, win-win co-operation has gradually been business spirit for modern enterprise management. High-tech virtual enterprise (HTVE) is a new dynamic enterprise network organization mode depending on the high-tech enterprises provided with core capability and competitive strength, the market dynamics requirement satisfied, the network information technology support, other partners or organization non-equity collaboration selected coordination relationships improved and Optimized, the technology criterion released, innovated and predominated jointly, and coordination achievements free or paid sharing consisting of intellectual property rights, skills and information input. Establishing HTVE is the innovation for ordinary enterprise organization form and the upgrade for virtual enterprise in the high-tech dominant; those could distribute R&D risk from high-tech enterprise, effectively response to the consumer market uncertain, reduce the complexity from business management, and bring up sustainable competitive strength. HTVE could be defined as Multi-Agent with specific solving goals, simultaneously its multi-part negotiation decision need to be scientifically and rationally assigned and controlled with resource during alliance negotiation process based on analyzing conflicts from participants. However, the whole process involves individuals with different subordinations, conflicts with different types, which cause the differences among the Multi-Agent joint consultation condition and behavior. The coupling relationships have been decided as the interactive qualities of individual agent negotiation agenda existing among alliance conflict with all kinds of cause and effect relationship, parallel relationship and overlapping relationship. Therefore, the essence for HTVE group negotiation decision model is to depict multi-part, multi-goal and multi-stage consequent process under the imperfect information, it would determine virtual organization successful operation, acquire favorable economic effects and form internal trust among individuals.
Currently, the main methods of Multi-Agent group negotiation decision around using the collaboration game theory, establishing negotiation model and dealing with the conflict contradiction among individuals. The majority discuss static state negotiation, in which the factors before the formal negotiation couldn’t change during the process. More often than not, however, the exact opposite is true that the certain factors independently or interactively as the HTVE negotiation. HTVE group negotiation should focus on the external influence factors, coexist relations between current process and other process. Next, multi-goal negotiation could increase the complexities facing diverse decision-making risk and business stage. Above all, bargaining issues decomposed and process complexities reduced legitimately is the important element for HTVE effective negotiation mechanism to improve alliance conflict-resolution capability and group satisfactory level. In addition, HTVE individual Agent utilizes adversarial issues, personal beliefs and others mutual information to decision, the issue value equally has been constricted within the certain value range; those dynamics negotiation processes conductively support the rough consensus immediately. The paper set the HTVE actual operation as the background, provides group negotiation decision-making method with multi-goal combined planning, analyzes model operation mechanism and executive structure, analytic demonstrates and develops the algorithms and procedures by the logical experiment.

2. Literature commentaries

Multi-Agent negotiation becomes commonplace as the distributed artificial intelligence development, Rosenschein and Zlotkin(1994) propose negotiation specified descriptions among computers. New theory and method constantly is emerged due to Multi-Agent application domain, Lomuscio etal. indicate negotiation is the key technology to the second E-commerce system[11]. Faratin etal. use negotiation decision function-NDF as the formal negotiation basis and supply the individual issue and individual stage bargaining model[4]. Kung-Jeng et al. Analyze NDFs convergence characteristic constricted within negotiation deadline[5]. Fatima etal. provide Multi-Issue negotiation framework faced to endogenous agenda[6]. Dajun Zeng et al. bring forward the negotiation quence decision-making model called Bazaar, it uses bayes’ beliefs to update negotiation learning, sequence negotiations are improved during the interactive learning, but the ordinary quoted price process among agent is reflected in its single-phase negotiation researched[7]. Fatima et.al. establish the agenda-based negotiation framework for Multi-Issue[8]. Negotiation is the open, complex interactive process, Jennings et al. believe the integral negotiation involves the three factors, such as negotiation protocols, negotiation objects and agent’s decision-making model[9].

Negotiation is divided as cooperative negotiation and non-cooperative negotiation. The former feature mainly centers on seeking the best collation utility and assignment protocol by cooperation, the latter centers on getting the most individual profit by special strategy. Two kinds negotiation exist in the real belonging to the cooperative negotiation as the research mainstream, which are popular in the network information fields. The domestic researchers around collaboration negotiation are interested formal description model by Agent state of mind, Agent negotiation reasoning process and Agent negotiation decision mechanism and Agent communication input-output primitive. Xiao Y provides the framework model for Multi-Agent auto negotiation system with Web Service technology, selective analyzes the framework model composing of negotiation agent, negotiation register center and negotiation service[10]. Han W supplies Multi-Agent online learning and collaboration learning method based on self-examination reasoning for negotiation game theory, establishes transaction agent one-to-one negotiation model based on self-adaption fuzzy reasoning[11]. Liu SY sets up negotiation model of agent supply chain system expanding game theory[12]. Li L described the over whole life cycle supporting virtual enterprise by agent, under its structure studies on negotiation method to inner-enterprise cooperation and collaboration[13]. Ai FQ distinguishes and solves alliance conflict issues of virtual enterprise by the Agent feature of intelligence and autonomy[14]. Wang LM expands speculating computational models to multi-thread negotiation contained model, proposes Multi-Issue negotiation method with belief revision[15]. Huang XQ sets up grid resource managing and scheduling model based on Multi-Agent and SLA protocol against Multi-Agent and Multi-Issue negotiation process[16].

Zhang H creates individual negotiation utility model respectively, and subject to bilateral auto-bargaining mind state faced to Multi-Issue[17]. Zhou JP discusses supply chain auto-bargaining mechanism for collaboration agent and analyzes module management method and module interface relations for supply chain logistics[18]. Guo Q provides individual state of mind model and social state of mind model based on capabilities from ordinary rational balance theory[19]. Cheng Y etal. exploit the hidden information to tagging
data for training sample from negotiation history, then get the opponent utility function estimated by learning the samples with the method of least square method and Support Vector Machine (SVM), then establishes one constraint optimization model combined mutual utility functions [20].

Contrastive analyzing the domestic and foreign research current situation, the most research centers that Multi-Agent group negotiation process make individuals’ conscious state through a series of methods update mutual beliefs for reaching an agreement. However, the disadvantages are embodied in the social idea statement modification during the group negotiation, i.e. without having considered that agent influence to the alliance bargaining statement from the individual capability.

Without considering the constraint factors, such as negotiation sustainable time and surrounding in individual negotiation behavior, strategy integrated application and Multi-Issue complementation or alternation. Additionally, HTVE independent individual, constantly changing surroundings and benefits cause Multi-Agent negotiation uncertainty and fuzziness, thus HTVE Multi-Agent negotiation process modeling could be consider as the complex system decision composed of time dimension, assignment dimension, enterprise dimension and strategy dimension, as shown in Figure 1.

![Figure 1. Process modeling dimension for HTVE group negotiation decision](image)

Time dimension describes the time constraint relations between decision-making agenda waited for Multi-Agent group negotiation, assignment consists of negotiation issue determination, interrelations and group bargaining sequences, and enterprise dimension describes negotiation process influence by Multi-Agent personal utility and bargaining power, and strategy dimension focuses on the Multi-Agent conflict resolution and countermeasure reposing to negotiation environment.

It could clearly be seen that Multi-Agent group negotiation need to synthesize the various individual conflict-resolution capability and bargaining strategy from inside and outside, settle the contradictions between individual requirement complexity and capability limitation, those obtain the Multi-Agent negotiation Pareto balanced results during the bouts repeatedly to reach an agreement for HTVE win-to-win strategic goals, in accordance with individual utility bias and others negotiation information recognitions.

### 3. Multi-Agent negotiation process descriptions

HTVE group negotiation expresses the many issues accomplished dynamic series from Multi-Agent, generally, the single issue negotiation process could compose of the certain number of agenda sequence, the bout contains so much negotiation information, in which the agent puts forward the proposals according to belief, bias, opinion and others, then estimates the anti-proposal from other agent, contributing to individual satisfactions in a short time [21]. There into, the conceptions of HTVE negotiation structure are provided as follows:

**Definition 1** $i$ represents $Agent_i$ accession order number ($i = 1, 2, ..., k + l$) of HTVE, against different negotiation protocol $j$, $Agent_{ij}$ is defined as negotiation agenda with various $Agent_i$, even $i \in I_j$. $MA_{ij}$ refers to HTVE individual numbers for the issue $j$ of $Agent_{ij}$.

**Definition 2** Pending New issue $j$ ($j = 1, 2, ..., m$) is related to $Agent_i$ proposal at $t_e$, even $e \in N$(is the natural numbers set). $m$ represents pending new issue numbers, $C_{ij}(t_e)$ refers to attribute value of pending new issue.
Initiator Agent provides new issue value to other Agent called proposal, accordingly anti-proposal appears in contradiction; both are the set of feature consisting of variables. Proposal from Agent could be represented as point value or interval value, \[ C^p_{i,j}(t_e) \leq C^o_{i,j}(t_e) \leq C^u_{i,j}(t_e) \].

Individual proposal interval points estimating or reasoning results from intention, possible negotiation proposal, and strategy between \( i \)-th Agent and others. When \( C^o_{i,j}(t_e) = C^p_{i,j}(t_e) \), Agent\( i \) proposal point could be regards as the special case of interval, therein \( C^i_{i,j}(t_e) \) is \( i \)-th Agent proposal value, thus \( C^i_{i,j}(t_e) \) could be depicted as the proposal interval value for issue \( j \) at \( t_e \).

**Definition 3** \( t^i_{max} \) is the negotiation end time for issue \( j \), even \( 0 \leq t^i_j \leq t^i_{max} \). \( t^i_{max} \) should be decided from bargaining frequency and agreement reached rate from issue \( j \).

**Definition 4** \( U(C^i_j) \) refers to Agent\( i \) individual utility function for issue \( j \), even \( 0 \leq U(C^i_j) \leq 1 \). \( C^*_{i,j} \) is Agent\( i \) proposal expected value when \( U(C^i_j) \) reaches optimum state, even \( C^*_{i,j} \in [C^o_{i,j}(t_e), C^u_{i,j}(t_e)] \). Agent\( i \) evaluates every proposal by \( U(C^i_j) \) to individual bias level accordingly, then Agent\( i \) determines the issue intervals next agenda or negotiation terminated.

**Definition 5** \( \omega_{i,j} \) represents Agent\( i \) relative bargaining power for issue \( j \), even \( \sum_{j=1}^{n_I} \omega_{i,j} = 1 \).

**Definition 6** \( W_j \) refers to issue \( j \) weights decided by Agent\( i \), even \( \sum_{j=1}^{n_I} W_j = 1 \).

**Definition 7** negotiable range is Agent\( i \) approving intervals to issue \( j \) at \( t_e \), HTVE individual could establish the proposal range during negotiation process, even point value of interval should be changed continuously, \( D_j(t_e) \) refers to bargaining intersection among HTVE individual , just \( D_j(t_e) = \bigcup_{i=1}^{n_I} [C^o_{i,j}(t_e), C^u_{i,j}(t_e)] \). and \( \min\left[ C^u_{i,j}(t_e) \right] \leq D_j(t_e) \leq \max\left[ C^o_{i,j}(t_e) \right] \).

**Definition 8** Agent\( j \) bargaining joint goal expresses Agent\( i \) perfect results for issue \( j \). HTVE Agent behavior is restricted by the multiple impact factors, \( C^*_j(t) \) makes up of \( C_j(t) \) responding to basic negotiation break-even point and \( \lambda^*_j(t) \) responding to negotiation Coefficient Vector to control, \( \bigcup_{j=1}^{n_I} C^*_j(t) \) and refers to joint negotiation goals from all \( n \) issues.

**Definition 9** issue \( j \) bargaining schedule is the agenda dealing procedures and steps. In general, Serial, Parallel and Mix Column are the substantial conflict-resolution styles. Serial is settled in departing \([0,t_{max}]\) and carry on the issues assignments individually. Parallel is simultaneous processing to issues in \([0,t_{max}]\), mix column combines the first two types, \( t_{max} \) is the end time for Multi-Issue of HTVE, the specific operation sequence is as shown in Figure 2.
Figure 2. Multi-Issue negotiation schedule types

Definition 10 $Q_{ij}(t)$ refers to Agent$_i$ voting results to issue $j$ within the prescribed time. When $Q_{ij}(t)$ equals to 0, it represents Agent$_i$ rejecting to the operational agreement. When $Q_{ij}(t)$ equals to 1, it represents Agent$_i$ accepting the operational agreement, even $Q_{ij}(t) = \prod_{i \in I_j} Q_{ij}(t)$. The statement is transformed as shown in Figure 3.

Figure 3. Result transforming relations for group negotiation

(1) when $0 \leq t \leq t_{\text{max}}$,

$$Q_{ij}(t) = \begin{cases} 0 \rightarrow & \text{individual proposal interval or other constraints are modified} \\ 1 \rightarrow & \text{individual proposal reach to agreement in issue } j \end{cases}$$

(2) when $t > t_{\text{max}}$,

$$Q_{ij}(t) = \begin{cases} 0, \text{ and } \sum_{i \in I_j} Q_{ij}(t) = 0 \rightarrow & \text{breakup} \\ 0, \text{ and } \sum_{i \in I_j} Q_{ij}(t) \geq 1 \rightarrow & \text{deadlock} \\ 1 \rightarrow & \text{issue } j \text{ is reached to agreement, modifying } \delta_{ij} \text{} \text{ finished} \end{cases}$$

Here, $\delta_{ij}$ is the discount factor for negotiation goal $C_{ij}^i(t)$, even $0 \leq \delta_{ij} \leq 1$. 
4. Establishing combined programming model for HTVE group negotiation decision-making

HTVE Multi-Agent switches on multi-stage negotiation to the certain issue for a limited time. In its infancy, individual need to estimate and divide its own decision space, combining the utility distributed trait to set up individual proposal, for waiting others’ reactions.

According to Multi-Agent bargaining power, HTVE Multi-Agent determine the joint proposal district and basic bargaining point, it could be defined as HTVE joint negotiation rough-bargaining planning. The aim of rough-bargaining planning is to the well-known and instructive original space of decision function during the whole negotiation process, in a way, the rough-bargaining is regarded as the essential constraint range. Correspondingly, during the negotiation adjustment, individual adopts the different bargaining strategies to move the basic bargaining point by the influence on the external environment; the joint bargaining balance is the individual Agent negotiation result at the special time, it could be defined as HTVE group negotiation thick-bargaining.

Thick-bargaining is given expression to Multi-Agent coping abilities to the external environment on the condition of incompleteness information, the alliance corporation relationships is improved by the interactive learning among enterprises, amending and upgrading the negotiation strategy opportune. Multi-Agent decision-making model of the combined schedule negotiation is the quantitative analysis to individual rough-bargaining and thick-bargaining under the win-win demands, reducing HTVE management cost and communication cost, driving individual initiative from knowledge innovations and technological changes and assisting the alliance advanced resource shared.

4.1. Assumptions for decision-making model

Establishing the negotiation model needs to describe effectively individual bargaining issue, reflect the dynamic characteristic of interactive negotiation and supply the bargaining protocol flexibly and alternatively for Multi-Agent. Combining the basic conditions from negotiation model by Rubinstein, it could be assumed as follows for HTVE Multi-Agent negotiation.

(1) The computing resource for HTVE Multi-Agent negotiation is limited. We could divide the Zone of Possible Agreement through the individual considerable negotiation, for the uniformity bargaining balance finally. During the period, The Computational Complexity of negotiation problem would be happened unavoidably, specially, individual interactive behavior reasoning could cause individual beliefs update opportunely, it need to amend Agent proposal and the alliance targeted programs for negotiation part benefits and integrated benefits balance realized.

(2) HTVE Agent is the selfish individual pursuing the personal maximum utility and individual limited reason for decision behavior. Multi-Agent could get the issue basic bargaining point by joint negotiation and adopt various strategies responding or exploiting the internal and external constraints for making hay out of benefits. Those could make the final bargaining issue value approach to the personal optimum utility expectations, realizing the individual benefits acquired by joining HTVE in contrast to independent operation.

The collective rationality condition and part rationality condition satisfied are explained that the interest of alliance is greater than the sum of individual interest, accordingly, the individual benefits acquired by joining HTVE is greater than other organization form benefit. Notably particularly, Agent is provided with the limited rationality, and then Agent must be satisfied one of the three rationality hypothesis as follows:

Hypothesis1: Rationality assumption is regarded as the opposition behaviors randomly.

Hypothesis2: discrete rationality assumption is regarded as the opposition behaviors independently.

Hypothesis3: unique rationality assumption is regarded as the opposition behaviors knowable partly.

(3) Multi-Agent group negotiation behaviors is the dynamic cooperation and competition process under non-perfect information, and Multi-Agent could reach the good faith negotiations, avoiding deceit and Malicious Intent happened and affected. During HTVE group negotiations, agent is provided with incomplete knowledge, non-cognitively having other opponents’ bias information, Agent need to adjust its strategy goals and alliance structure by organization learning. It not only guarantees Multi-Agent (stakeholders) acquiring the satisfying benefits, but also maximizes HTVE interests of the whole for improving HTVE comprehensive strength.
(4) Multi-Agent negotiation agenda arrangement of HTVE requires manager Agent unified allocation of resources and control process in the influence of bargaining time, negotiation resource relative factors. When any factor changes, individual must adjust its bargaining scheme and behavior immediately, avoiding the multilateral deadlocked negotiation, it is the worst consequence from the failure of negotiation.

(5) Individual proposal utility function of Partner agent is the non-stationary mode, dynamically changing by negotiation process depth and the individual best utility expected point would also shifted and updated. Facing to the complex issue with complement or independent relations, group negotiation puts the individual bias from different issues in orders, combined analyzes their utilities distribution and interests pattern, and then decide to HTVE planning goal for group negotiation.

4.2. Derivations for zone of Possible Agreement and bargaining point

The zone of possible agreement is defined as the joint bargaining zone from HTVE individual agent proposal intervals. Agent, Proposal points changes in different \( t_e \), that is different \( D_i(t_e) \) in the corresponding time. We could link individual bargaining power to discuss the agent zone of possible agreement and basic bargaining balance point, and deduce Multi-Agent joint acceptable area and issue bargaining value on the any issue, it could be called the derivation method for \( D_i(t_e) \) and \( C_{ij}(t_e) \).

In case, HTVE conflict issue has been settled, it also could be notified the issue bargaining direction and issue intervals. Without considering HTVE agent strategy adopted, it could be described as the basic bargaining balance point adjustment in the accepted district. When every HTVE Agent, \((i = 1, 2, ..., k, ..., k + l, ..., m)\) interact on the certain issue, they first select and decompose the conflict-resolution, find the corresponding relations between issue \( j \) and participant agent \( I_j \). Then Agent, \((i \in I_j)\) synthetically evaluates other Agent, \((i \in I_j)\) decision-making behavior and set proposal \([C_{ij}^p(t_e), C_{ij}^q(t_e)]\) at \( t_e \), the individual proposal intervals could be formed intersect \( \bigcup_{r=1}^{r'} D_i^r(t_e) \) with \( r \) item, so

\[
\bigcup_{r=1}^{r'} D_i^r(t_e) = \bigcup_{r=1}^{r'} \bigcap_{i \in I_j} (C_{ij}^p(t_e), C_{ij}^q(t_e))
\]

Here, \( r' = 1, 2, ..., MA_j \). In regard to any \( D_i^r(t_e) \), it could be regarded as Agent, proposal interval overlapped, \( g_{ij}^r \) is the happening frequency in \( r = r' \) for several Agent, and \( g_{ij}^r = 0 \) or \( 1 \). For example,

\[
\begin{array}{ccccccc}
\text{Agent}_1 & \text{Agent}_2 & \cdots & \text{Agent}_{k-1} & \text{Agent}_k & \cdots & \text{Agent}_{k+l} \\
1 & 1 & \cdots & 1 & 0 & \cdots & 0 \\
0 & 0 & \cdots & 1 & 0 & \cdots & 0 \\
\cdots & \cdots & \cdots & \cdots & 0 & \cdots & \cdots \\
1 & 0 & \cdots & 1 & 0 & \cdots & 0 \\
\sum g_{ij}^r & 2 & 1 & \cdots & 3 & 1 & \cdots & 0
\end{array}
\]

Case 1 If Agent, \((i = 1, 2, ..., k, ..., k + l, ..., m)\) proposal is located in \( \bigcup_{r=1}^{r'} D_i^r(t_e) \), \( g_{ij}^r \) could be selected 0 or 1. When \( g_{ij}^r = 0 \), it represents that forming reason of \( D_i^r(t_e) \) is unrelated to Agent, . When \( g_{ij}^r = 1 \),
it represents that forming reason of $D'_{ij}(t_e)$ is related to $\sum_{r=1}^{j} g'_{r,ij}$ is deem as the frequency from every proposal overlapping area, even $\sum_{r=1}^{j} g'_{r,ij} \geq 1$.

**Case II** If $Agent_i (i = 1, \ldots, k - 1)$ proposal is located on the left side of matrix of $\bigcup_{r=1}^{j} D'_{ij}(t_e)$, and other $Agent_i (i = k, \ldots, k + l)$ proposal keeps the relative independence statement with $D'_{ij}(t_e)$ on the right side of matrix. Even these negotiation individual proposals set could be express as $\bigcup_{r=1}^{k+l} [C_{ij}(t_e), C'_{ij}(t_e)]$. It could be clear seen that, the former is $g'_{r,ij} = 0$ or $1$, and $\sum_{r=1}^{j} g'_{r,ij} \geq 1$. The latter is $g'_{r,ij} = 0$, and $\sum_{r=1}^{j} g'_{r,ij} = 0$.

**Case III** If $Agent_i (i = 1, \ldots, k, \ldots, k + l)$ proposal intervals are independent, individual proposal set of HTVE is $\bigcup_{i=1}^{k+l} [C'_{ij}(t_e), C''_{ij}(t_e)]$.

Against the three cases mentioned about individual proposal distribution, it forms the joint zone of possible agreement $D'_{ij}(t_e)$ for Multi-Agent and single-issue at $t_e$ and basic bargaining point $C'_{ij}(t_e)$. Supposing basic bargaining pint $C'_{ij}(t_e)$ responds to zone $D'_{ij}(t_e)$, so the formula (1) is as follows.

$$C'_{ij} = \frac{\sum_{r} \omega_{r,i} C'_{r,ij}}{\sum_{r} \omega_{r,i}}$$

We could obtain the relative results correspondingly as follows.

**Proposition I** It gets the formula (2) through $Agent_i (i = 1, \ldots, k + l)$ mutual bargaining.

$$D_{ij}(t_e) = \left[\min(C'_{ij}, C''_{ij}), \max(C'_{ij}, C''_{ij})\right]$$

$$E_{ij}(t_e) = \left[-\min(C'_{ij}, C''_{ij}), \max(C'_{ij}, C''_{ij})\right]$$

$$C_{ij}(t_e) = \frac{\sum_{r=1}^{j} g'_{r,ij} \cdot \omega_{r,i} C'_{r,ij} + (\sum_{r=1}^{j} g''_{r,ij} \cdot \omega_{r,i} C''_{r,ij}) + \ldots + (\sum_{r=1}^{j} g'_{r,ij} \cdot \omega_{r,i} C'_{r,ij}) + \ldots + (\sum_{r=1}^{j} g'_{r,ij} \cdot \omega_{r,i} C'_{r,ij}) + \ldots + (\sum_{r=1}^{j} g''_{r,ij} \cdot \omega_{r,i} C''_{r,ij})}{(\sum_{r=1}^{j} g'_{r,ij}) \cdot \omega_{r,i} + (\sum_{r=1}^{j} g''_{r,ij}) \cdot \omega_{r,i} + \ldots + (\sum_{r=1}^{j} g'_{r,ij}) \cdot \omega_{r,i} + \ldots + (\sum_{r=1}^{j} g''_{r,ij}) \cdot \omega_{r,i}}$$

(2)
Proposition II Any Agent $\{i = k, ..., k+l\}$ proposal could be $C_{k,i}^{\prime}, ..., C_{k+l,i}^{\prime}$ in the individual interval, intersecting with Agent $\{i = 1, ..., k-1\}$ proposal to form $C_i^{\prime}$ sorted, we get the formula (3) as follows.

$$D_i(t_i) = \left[ \min(C_i^{\prime}, C_{i+1}^{\prime}, ..., C_{k,i}^{\prime}, C_{k+1,i}^{\prime}), \max(C_{k+1,i}^{\prime}, C_{k+2,i}^{\prime}, ..., C_{k+l,i}^{\prime}) \right]$$

$$E_i(t_i) = \left[ \max(C_i^{\prime}, C_{i+1}^{\prime}, ..., C_{k,i}^{\prime}, C_{k+1,i}^{\prime}) - \min(C_i^{\prime}, C_{i+1}^{\prime}, ..., C_{k,i}^{\prime}, C_{k+1,i}^{\prime}) \right]$$

$$C_i(t_i) = \frac{\sum g_{i,j}^{k,j} \cdot \omega_{i,j} + \sum g_{k+1,j}^{k+1,j} \cdot \omega_{k+1,j} + \sum g_{k+2,j}^{k+2,j} \cdot \omega_{k+2,j} + \sum \omega_{k+l,j} \cdot C_{k+l,i}^{\prime}}{\sum \omega_{i,j} + \sum \omega_{k+1,j} + \sum \omega_{k+2,j} + \sum \omega_{k+l,j}}$$

(3)

Proposition III Agent $\{i = 1, ..., k, ..., k+l\}$ is provided with $C_{i,j}^{\prime}, ..., C_{k,i}^{\prime}, ..., C_{k+l,i}^{\prime}$ by individual bias trend among the proposal intervals, we sort ascending to get the formula (4) as follows.

$$D_i(t_i) = \left[ \min(C_{i,j}^{\prime}, C_{i+1,j}^{\prime}, ..., C_{k,j}^{\prime}, C_{k+1,j}^{\prime}), \max(C_{k+1,j}^{\prime}, C_{k+2,j}^{\prime}, ..., C_{k+l,j}^{\prime}) \right]$$

$$E_i(t_i) = \left[ \max(C_{i,j}^{\prime}, C_{i+1,j}^{\prime}, ..., C_{k,j}^{\prime}, C_{k+1,j}^{\prime}) - \min(C_{i,j}^{\prime}, C_{i+1,j}^{\prime}, ..., C_{k,j}^{\prime}, C_{k+1,j}^{\prime}) \right]$$

$$C_i(t_i) = \frac{\omega_{i,j}C_{i,j}^{\prime} + \omega_{i+1,j}C_{i+1,j}^{\prime} + \omega_{i+2,j}C_{i+2,j}^{\prime} + \omega_{k+l,j}C_{k+l,j}^{\prime}}{\omega_{i,j} + \omega_{i+1,j} + \omega_{i+2,j} + \omega_{k+l,j}}$$

(4)

HTVE joint group negotiation should be handled properly in line with the principles of mutual respect, seeking common ground while putting aside individual and making the identified and fair agreement. Because HTVE individuals are drowed by part benefits during conflict resolved, every Agent positively make hay out of the decision-making mode and utility constitution, Multi-Agent zone of possible agreement and balance bargaining point need to combine individual bias and bargaining powers for realizing the method extensive domain and application area. Secondly, HTVE Multi-Agent group negotiation is provided with temporality, the principle is that individual evaluate the basic bargaining point, analysis others proposal successive change law, and then adjust individual proposal width and ends of an interval, update the zone of possible agreement and balance point until getting group negotiation decision-making goal, we could define the process as HTVE multiples attribute sequential decision-making under the conflict of opinion.

HTVE individual share the negotiation resource and decide to solve group conflicts by mutual trust, the co-operation consciousness and statement supplies the norm for the repeat negotiation of different agent facing the same issue, it favors in promoting HTVE business efficiency and operation effects, avoiding the alliance risk and economic loss.

4.3. Establishment of combined programming model for group negotiation

The basic balance point of joint bargaining is HTVE individual basic targeted value for every conflict bias and value judgments by mutual manner. HTVE conflict-solution process could be effect on several uncertainties, individual proposal expectation and coping strategy would change consequently, those cause joint zone of possible agreement and balance point to dynamic adjustment. When the new accepted area and negotiation point locate in the non-active status, the fairness bargaining result would be formed for HTVE Multi-Agent negotiation. The conclusion synthetically analyzes the group internal condition and external controlling constraints, promoting the final results accepted by all negotiation agents.
(1) Combined programs model of single-issue group negotiation

HTVE Agent, bargains with issue \( j \), joint bargaining point \( C^*_j(t_e) \) moves basic balance point \( C_j(t_e) \) to get the accepted value located in the protocol intervals \( D_j(t_e) \). The moving direction and distance of bargaining balance point are up to \( \vec{\lambda}_{i,j}(t_e) \) as negotiation regulatory coefficient. Regulatory capability vector to external factors of Joint negotiation alliance \( Agent_j \) could be expressed by \( \vec{C}_j(t_e) \), consisting of several \( \vec{\lambda}_{i,j}(t_e) \) as individual \( Agent_i \) regulatory component of vector, that is \( \vec{\lambda}_{i,j}(t_e) = \sum_{i=1}^{k+l} \vec{\lambda}_{i,j}(t_e) \). Any \( \vec{\lambda}_{i,j}(t_e) \) disposes \( \vec{C}_j(t_e) \) to adjoin \( C^*_j(t_e) \) in area \( D_j(t_e) \), it can clearly be seen that the relative positions of \( C^*_j(t_e) \) and \( C_j(t_e) \) determine the form of expression \( \vec{\lambda}_{i,j}(t_e) \), as the formula (5).

\[
\vec{\lambda}_{i,j}(t_e) = \begin{cases} 
\lambda_{i,j}(t_e) & C^*_j(t_e) \geq C_j(t_e) \\
-\lambda_{i,j}(t_e) & C^*_j(t_e) < C_j(t_e) 
\end{cases}, \quad (5)
\]

\[
\sum_{i=1}^{k+l} \lambda_{i,j}(t_e) \quad \text{and} \quad \sum_{i=k+1}^{l+k+l} \lambda_{i,j}(t_e)
\]

are for negotiation regulatory coefficient sum located on the left (\( Agent_{1,2,\ldots,k+l} \)) and the right (\( Agent_{k+1,k+2,\ldots,l+k+l} \)) of bargaining balance point. \( \lambda'_{i,j}(t_e) \) is individual \( Agent_i \) exerting its collaboration level facing to many external constraint \( s \) required by \( \lambda_{i,j}(t_e) \). Namely, \( \lambda_{i,j}(t_e) \) is the continuous function on \( \lambda'_{i,j}(t_e) \), then \( \lambda_{i,j}(t_e) = F(\lambda'_{i,j}(t_e), \lambda'_{i+1,j}(t_e), \ldots, \lambda'_{i+k+l,j}(t_e)) \). With joint bargaining point \( C^*_j(t_e) \) of issue \( j \) from \( Agent_i \), then

\[
C^*_j(t_e) = C_j(t_e) + \vec{\lambda}_{i,j}(t_e) E_i(t_e)
\]

\[
= C_j(t_e) + [\vec{\lambda}_{1,j}(t_e) + \vec{\lambda}_{2,j}(t_e) + \ldots + \vec{\lambda}_{l,k+l,j}(t_e)] E_i(t_e), \quad (6)
\]

Any \( Agent \) expect the joint bargaining value adjoining or reaching to its proposal expected point, we take the sum of squared distance between \( C^*_j(t_e) \) and \( C^*_j(t_e) \) as the decision -making negotiation goal function on issue \( j \), \( \lambda_{i,j}(t_e) \) as individual bargaining regulatory coefficient is deem to the constraint condition.

Suppose \( L_{i,j}(t_e) = |C^*_j(t_e) - C_j(t_e)| \), we could establish the following model,

\[
F_i(t_e) = Min \sum_{i=1}^{l+k+l} \left| C^*_j - C_j(t_e) \right|^2, \quad (7)
\]

Extended,

\[
Min \sum_{i=1}^{l+k+l} \left| C^*_j - [C_j(t_e) + \vec{\lambda}_{1,j}(t_e) + \vec{\lambda}_{2,j}(t_e) + \ldots + \vec{\lambda}_{l,k+l,j}(t_e)] E_i(t_e) \right|^2, \quad (8)
\]
s. t. 
\[
\begin{aligned}
\left\{ \begin{array}{l}
\hat{\lambda}_{i,j}^{+}(t_e) + \hat{\lambda}_{2,j}^{+}(t_e) + ... + \hat{\lambda}_{k+1,j}^{+}(t_e) \leq \min_{L_{i,j}(t_e)} \frac{L_{i,j}(t_e)}{E_{i,j}(t_e)} \quad (9) \\
\sum_{i=1}^{k+1} \hat{\lambda}_{i,j}^{-}(t_e) \leq \sum_{i=1}^{k+1} \hat{\lambda}_{i,j}^{+}(t_e) \leq \sum_{i=1}^{k+1} \hat{\lambda}_{i,j}^{-}(t_e) \\
0 \leq \hat{\lambda}_{i,j}^{-}(t_e) \leq 1 \\
i \in I_e, 	ext{and } i = 1, k, ..., k+l
\end{array} \right.
\end{aligned}
\]

There into, formula (9) is the dynamic step constraint, it describes the adjustment area from $C_{i,j}^{+}(t_e)$ couldn’t large than area of $D_{i,j}(t_e)$, formula (10) is the dynamic ratio constraint, expressing the joint alliance negotiating by its regulatory capabilities. $\xi = [\xi_1, \xi_2]$ As intervals gives the regulatory capabilities contrast with joint $Agent_{i-k+1}$ and $Agent_{1,2,...,k}$, we could determine $\xi$ with bargaining position of strength contrast from HTVE joint alliance. Obviously, when $0 < \xi < 1$, joint $Agent_{1,2,...,k+1}$ has stronger negotiation capabilities than joint $Agent_{1,2,...,k}$, and $\sum_{i=1}^{k+1} \hat{\lambda}_{i,j}^{-}(t_e)$ also reflect the disposable bargaining resource totals in HTVE joint conflicts.

\[
\xi = \frac{\omega_1 + \omega_2 + ... + \omega_{k+l}}{\omega_1 + \omega_2 + ... + \omega_{k+l}} 
\]

It is known from single-issue decision-making negotiation model, individual $Agent_i$ proposal intervals should constantly change at $t_1, t_2, ..., t_e$, which cause the basic bargaining balance point $C_{i,j}^{+}(t_e)$ adjusted and modified. By solving targeted function as $F_{i,j}(t_e), F_{i,j}(t_2), ..., F_{i,j}(t_e)$, we get $\hat{\lambda}_{i,j}^{+}(t_1), \hat{\lambda}_{i,j}^{+}(t_2), ..., \hat{\lambda}_{i,j}^{+}(t_e)$. Therefore, $F_{i,j}(t_e)$ is relative to $t_e$, and min $F_{i,j}(t_e)$ is the optimized result of programs models.

(2) Combined programs model of Multi-Issue group negotiation

HTVE individual mutual bargains on Multi-Issue $j (j = 1,2,...,m)$, with different standard of care for $m$ single-issue $j$. For the targeted function of HTVE $Agent_i$ is used equally, we make HTVE manager $Agent$ give the relative importance as $W_j$ for issue $j$, even $\sum_{j=1}^{m} W_j = 1$. So the targeted decision-making functions for Multi-Issue group negotiation is shown as formula (12),

\[
\text{Min}[W_1 \sum_{i=1}^{m} C_{i,j}^{+} - C_{i,j}^{-}(t_e)]^2 + W_2 \sum_{i=1}^{m} C_{i,j}^{+} - C_{i,j}^{-}(t_e)]^2 + ... + W_m \sum_{i=1}^{m} C_{i,m}^{+} - C_{i,m}^{-}(t_e)]^2
\]

The regulatory coefficient of HTVE $Agent_i (i = 1, ..., k+l)$ on issue $j (j = 1,2,...,m)$ could be expressed as the matrix of $\hat{\lambda}_{i,j}^{-}(t_e)$ . When $\hat{\lambda}_{i,j}^{-}(t_e) = 0$, it represents that $Agent_i$ don’t participate in bargaining activity on issue $j$, then
Every Agent regulatory capability coefficient in Multi-Issue is relative to the relations of several issues, when issues relationships is independent and non-compensation, obviously, we get \( \lambda_1(t_e) = \ldots = \lambda_m(t_e) \); when issues is compensated with each other, we get \( \lambda_1(t_e) + \ldots + \lambda_m(t_e) = 1 \). \( \lambda_{ij}(t_e) \) could be described as formula (9) and (10) for any issue \( j \) among several Agent, therefore, the constraint conditions for targeted function give value range of \( \lambda_{ij}(t_e) \) from across and down dimensions to the same Agent on the different issue and different Agent on the same issue. To the across dimension, the constraint conditions have \( k + l \) as formula (13); to the down dimension, we get \( m \) series constraint formula (14), even constraint form and structure are the same.

\[
\begin{align*}
\lambda_1(t_e) &= \ldots = \lambda_m(t_e) \\
\lambda_{1,2}(t_e) + \ldots + \lambda_{1,m}(t_e) &= 1 \\
\quad \ldots \\
\lambda_{k,1}(t_e) + \lambda_{k,2}(t_e) + \ldots + \lambda_{k,m}(t_e) &= 1 \\
\quad \ldots \\
\lambda_{k+l,1}(t_e) &= \ldots = \lambda_{k+l,m}(t_e) \\
0 \leq \lambda_{ij}(t_e) &\leq 1
\end{align*}
\]

\[\left| \mathbf{\hat{\lambda}}_j(t_e) \right| \leq \min \left( \frac{L_{ij}(t_e)}{E_{ij}(t_e)} \right) \]

\[
\xi \sum_{i=1}^{k-1} \hat{\lambda}_{ij}(t_e) \leq \sum_{i=1}^{k+l} \hat{\lambda}_{ij}(t_e) \leq \xi \sum_{i=1}^{k-1} \hat{\lambda}_{ij}(t_e) \\
i \in I_j, \xi = 1, \ldots, k, \ldots, k + l \\
\sum_{j=1}^{m} W_j = 1
\]

For HTVE individual of Multi-Issue group negotiation, it is essential to find negotiation results balance among Multi-Issue, general balance relates to HTVE issue units and expected individual utility. After Individual Agent analyzes the complementary relationships among Multi-Issue, they could make Multi-Issue be the maximum utility by mutual bargaining, reducing the divergences with others about the same issues to theirs hearts content. The balance results availably are not the long-term outcome that Complete Rationality individual find optimums as time go by, but the revolting and learning outcome formed through a long course of development. However, the balance happening time and happening reasons in ordinary game theory could be received that the balance is individual analysis and Self-reflection results under the shared knowledge of game rule, participant rationality and pay-off functions. Those are over-idealized in HTVE group negotiation operation among Multi-Issue in practice; therefore, we must use dynamic evolutions to analyze Multi-Agent joint statement and behavior logic, decide individual proposal interval structure as the multi-round negotiation basis among Multi-Agent, which could be inserted in group decision-making negotiation model. When the
basic negotiation value couldn’t reach the satisfying consistency among HTVE Multi-Agent, joint bargaining alliance Agent need to adjust external constraint synthetically by negotiation strategies, making the negotiation results conform to the balance conditions and driving individual to mutual learn and knowledge innovation.

4.4. Operation mechanism for interactive combined negotiation model of HTVE

HTVE interactive group negotiation would guarantee individual dealing with the issues demand legitimately and opportunistically, the whole adjustment in practice depends on the dynamic negotiation mechanism among several individual. HTVE group negotiation mechanism integrates participants’ inclination, pushing the alliance visions formed and trust worthiness promoted. When the original cooperation protocol derivates from the actual situation, HTVE individual could reach an agreement by interactive negotiations, combined with revised issue balance point and make the appropriate readjustment to alliance protocols.

![Figure 4. Operation flow for Multi-Agent mutual negotiation model](image)

Generally, Multi-Agent decision-making negotiation model should observe the principles of steps as followed (Figure.4). Firstly, Multi-Agent mutual bargains on issue \( j \) at \([0, t_{\text{max}}]\), forming the zone of possible agreement, basic bargaining balance point and moving point area by individual negotiation power measured. Secondly, HTVE individual Agent responds to the external constraint by the negotiation strategy, and then the negotiation targeted programs model is established for joint bargaining point as Multi-Issue group negotiation final results. Once again, individual would vote on the joint bargaining results, and then provides the computable goal degree of reaching an agreement and the whole conflict level coefficient. If individual agent agrees to the conclusion, if the degree of consistency calculated is 1, the whole conflict level coefficient is 0; we could finish the issue bargaining process. Otherwise, individual agent is unsatisfied with the results, the degree of consistency calculated is 0, the whole conflict level coefficient is 1, and we could forecast and evaluate individual behavior to amend the proposal intervals for renewing the negotiation procedure. Finally, it is possible to find the best statement of HTVE joint utility by temporal series of targeted functions to enrich the Multi-Agent consistency on the certain issue; it would help HTVE individual select the balance joint bargaining point. Sometimes, Manager Agent uses case search or experiment analysis to coordinate individual the cooperative consciousness and behaviors, for solving the conflict
to reach an agreement. When we encounter the inextricable issues, the negotiation should bring us into a stalemate or breakdown. Therefore, the establishment of interactive negotiation model even can draft and update the cooperation protocol standard, and measure the alliance cooperation performance reference.

5. Empirical analyses

5.1. Empirical executions

We take the example of market selling price negotiation for the high-tech products, by means of Numerical simulations, and establish the combined programs functions for HTVE Multi-Issue group negotiation. Table 1 and Table 2 describe some experiment data about five \( Agent(i \in I) \) mutual negotiations at \( t_e \), the original experiment demonstrates that enterprises bargaining have brought us into a stalemate, and then we adopt the mentioned Multi-Issue combined programs to solve HTVE five individuals’ negotiation conflicts. from the formula (2), the basic bargaining point is \( C_{i_e}(t_e) = 131.97 \), the joint protocol intervals is \( D_{i_e}(t_e) = [110, 154] \), the zone width of possible agreement is \( E_{i_e}(t_e) = 44 \), then we could get the contrast ratio \( \xi = 1.08 \pm 0.02 \) as individual bargaining regulation capability. At last, the single-issue combined negotiation decision-making model among five individuals could be established for \( C_{i_e}(t_e) = 132.80 \) from formula (8) to (10).

<table>
<thead>
<tr>
<th>Agent, ( i )</th>
<th>([C_{i_{ij}}^H(t_e), C_{i_{ij}}^L(t_e)])</th>
<th>(C_{i_{ij}}^\ast(t_e))</th>
<th>(C_{i_{ij}}^L(t_e))</th>
<th>(\Delta C_{i_{ij}}^\ast(t_e))</th>
<th>(Q_{i_{ij}}(t_e))</th>
<th>(\omega_{i_{ij}}^\ast)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>[100,120]</td>
<td>105</td>
<td>143.5</td>
<td>15.5</td>
<td>1</td>
<td>0.33</td>
</tr>
<tr>
<td>2</td>
<td>[110,140]</td>
<td>110</td>
<td>143.5</td>
<td>10.5</td>
<td>1</td>
<td>0.15</td>
</tr>
<tr>
<td>3</td>
<td>[150,160]</td>
<td>154</td>
<td>143.5</td>
<td>-33.5</td>
<td>0</td>
<td>0.21</td>
</tr>
<tr>
<td>4</td>
<td>[135,150]</td>
<td>145</td>
<td>143.5</td>
<td>-24.5</td>
<td>1</td>
<td>0.07</td>
</tr>
<tr>
<td>5</td>
<td>[120,155]</td>
<td>150</td>
<td>143.5</td>
<td>-29.5</td>
<td>0</td>
<td>0.24</td>
</tr>
</tbody>
</table>

Table 2. The experiment numeric for single-issue negotiation among HTVE five individuals at \( t_e \) under combined programs

<table>
<thead>
<tr>
<th>Agent, ( i )</th>
<th>([C_{i_{ij}}^H(t_e), C_{i_{ij}}^L(t_e)])</th>
<th>(C_{i_{ij}}^\ast(t_e))</th>
<th>(L_{i_{ij}}(t_e))</th>
<th>(g_{i_{ij}})</th>
<th>(\omega_{i_{ij}}^\ast)</th>
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<tr>
<td>1</td>
<td>[100,120]</td>
<td>105</td>
<td>110</td>
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<tr>
<td>2</td>
<td>[110,140]</td>
<td>110</td>
<td>110</td>
<td>21.97</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>[150,160]</td>
<td>154</td>
<td>154</td>
<td>22.03</td>
<td>1</td>
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<td>140</td>
<td>8.03</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>[120,155]</td>
<td>150</td>
<td>150</td>
<td>18.03</td>
<td>2</td>
</tr>
</tbody>
</table>

5.2. Empirical result analysis

From the mentioned empirical performing steps, we could get the empirical result as Figure 4. If HTVE individual makes joint bargaining goals press close to individual proposal expected value at the certain time, it reflects that joint proposal utility reaches the best balance statement at current moment, and then the individual benefit would be maximization. Effect of \( \min F_{i_{ij}}(t_e) \) is embedded in three
aspects as follows, (1) $t_e$ is deem as the last moment decision basis for the repeat negotiation on issue $j$. (2) individual proposal intervals depend on other Agent proposal forecasting and evaluating from Agent, the intervals width and location under the optimal targeted function could strengthen multi-agent negotiation behavior recognition and analysis rationality, improve and promote the cooperation relationships among enterprises of HTVE. (3) $C_j^*(t_e)$ is the best proposal value of issue $j$ reached among HTVE Agent, variable $\lambda_j(t_e)$ supplies the reference worth in individual adjustment and control capability to external constraint, helps individual negotiation strategies formed and other strategic information.

![Graph of Decision-making negotiation experiment analysis on the single-issue combined programs among HTVE five individuals](image)

**Figure 4.** Decision-making negotiation experiment analysis graph on the single-issue combined programs among HTVE five individuals

### 6. Conclusions

Interactive group negotiation for HTVE multi-agent is targeted at optimal balance reached between alliance joint utility and individual art utility, the constraints conditions are set to individual controlling capability, those could guarantee conflict-resolution fairness and equality, and individual joining in HTVE profits are greater than independent profits. Before group negotiation, individual Agent selects its own proposals and actions by part utility, called incentive compatibility. Establishing multi-goal combined programming negotiation model is based on the conflict issue departed and filtered, synthetically considering individual bias level, bargaining power and strategy to keep everyone mutual believe and depend by forecasting and recognizing the uncertain factors, these help increasing members benefit beliefs and prospect of HTVE and individual benefit consistency.

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8. References