Achieving Satisfied Virtual Exchange Rates through Multiple-Stage Virtual Money Supply

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Abstract*-An important research problem in designing an open virtual world is how to enable virtual currency exchange between multiple virtual worlds and guarantee the exchange fairness when multiple virtual currencies are adopted as virtual payment instruments in virtual trades between virtual worlds. While an existing VMX theory solved the fairness problem in a VERA algorithm based on a Pareto exchange point [3], a new expecation problem has been found such that exchange requesters might submit minimum acceptable rates (MAR) to determine whether to accept VMX systems-generated virtual currency exchange rates. When exchange requestors think the systems-generted rates are lower than MAR, they select not to accept the systems-generated rates. The withdrawal of systems-generated rates creates the expectation problem such that the fairness has been lost due to Pareto exchange point no longer exists. To solve the expectation problem, this paper has developed a new VERA-RS algorithm by extending the existing VERA algorithm based on a newly developed formal expectancy model and a novel m-stage and n-phase three-level computing framework. VERA-RS algorithm has solved expectation problem by achieving a set of satisfied virtual currency exchange rates.

Keywords: virtual world; virtual money; virtual currency; exchange rate; virtual wealth protection; algorithm

I. Introduction

Virtual money or virtual currency is a special type of virtual good that can be used to store the value of other virtual goods like traditional money. It is virtually created for or from virtual activities by virtual world participants (i.e. avatars) [2][9]. It is an abstraction of virtual wealth and is a virtual payment instruments in virtual worlds. It is used to leverage virtual economical activities and measure virtual economic scales [4]. An extremely important research problem in designing an open virtual world is how to enable virtual currency exchange between multiple virtual worlds and guarantee the exchange fairness when multiple virtual currencies are adopted as virtual payment instruments in virtual trades between virtual worlds.

To solve this problem, most existing industrial solutions adopt a close method - admitting only a single virtual world and creating a single virtual currency that supports all virtual product exchanges [1][12]. This solution does not accept the virtual trades between virtual worlds. Examples of using this method are most online worlds such as battle.net, qq.com and secondlife.com. To enable virtual trade across virtual worlds, some online virtual money exchange shops were created such as gameusd.com and ige.com. They sell multiple virtual currencies via real money. However, this method still cannot provide direct virtual currency exchange between virtual worlds and has some legal issues in some country. For example, in China, real money can buy virtual money but the reversal purchase is prohibited. To allow direct virtual currency exchange and guarantee the fairness of virtual currency exchange between virtual worlds, Guo et al [3] proposed a theory of virtual money exchange to protect virtual wealth (abbr. VMX Theory). This theory creates fair virtual money exchange rates between multiple virtual currencies based on a Pareto exchange point. It guarantees that any virtual exchange between any two virtual worlds is fair. It proved that all virtual exchanges can be established on a common value system such that sellers' intended selling value is equivalent to buyers' intended buying value at Pareto equilibrium points.

VMX Theory developed by Guo et al [3] is important. It first time solved the problem of virtual exchange between virtual worlds and first time theorized an approach of how to guarantee the fairness of virtual money exchange. Nevertheless, VMX Theory on fairness guarantee of multi-world virtual exchange can be further deepened and perfected. The reflection is: when a set of virtual currency exchange rates is obtained based on a Pareto exchange point at the sellers' intentions and buyers' intentions, some sellers and buyers may find that the given exchange rates (i.e. computed rates on a Pareto exchange point) are beyond their expectations. For example, a seller attempts to sell 1000 units of his virtual currency X for certain amount of virtual currency Y. When the exchange rate has been computed and given as Y8/X based on Pareto exchange point, the seller might think that his expectation is Y10/X, that is, using 1 unit of his X to trade back 10 units of desired Y but not 8 units of Y. Obviously, VMX Theory does not support users' virtual exchange rate expectations though users' adjustment on expected rates is provided (*see* Section 6.3 of Guo et al [3]).

The above-mentioned problem implies that the existing VMX Theory must be further developed not only to guarantee the fairness of virtual money exchange rates as the original theory offers but also to satisfy the virtual money exchange rate expectation of users.

This paper aims at extending VMX Theory to satisfy users' virtual money exchange rate expectations. To achieve this goal, this paper develops a formal expectancy theory above VMX Theory, such that expected virtual exchange

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rates are always obtainable by excluding unexpected virtual exchange rates. Applying the new expectancy theory, this paper proposes a new algorithm called VMX Exchange Rate Algorithm by Reduced Supply (VERA-RS), which is an algorithm, working on VMX Exchange Rate Algorithm (VERA) [3], to compute satisfied virtual exchange rates.

The rest of the paper is arranged as follows. Section 2 briefly introduces VMX Theory and discusses related works on expectancy models. Section 3 proposes a formal expectancy model. Section 4 designs a new VERA-RS algorithm to solve expectation problem. Section 5 makes a discussion and concludes the paper.

II. RELATED WORK

A. VMX Theory

In 2011, Guo et al [3] first time proposed a theory of virtual money exchange (VMX Theory) to protect the virtual wealth accumulated in large number of virtual worlds such as online games and metaverses [6]. The general idea of VXM Theory can be summarized as follows: (1) virtual wealth is protected if there exists free virtual wealth flow between virtual worlds; (2) virtual wealth freely flows between virtual worlds if there exists fair virtual money exchange rates between virtual worlds; (3) fair virtual money exchange rates exist if there exists a Pareto exchange point, at which sellers' total supplied value of one virtual world (i.e. intrinsic value of virtual goods of one virtual world) equals to buyers' total demanded value of other virtual worlds (i.e. extrinsic value or exchangeable value of virtual goods of other virtual worlds).

In this theory, fairness is a key concept for virtual wealth protection and technically relies on Pareto exchange points of sellers' total value and buyers' total value. The Pareto exchange points in time series constitute many fair exchange rate curves, on which, at a particular time point, equivalent common values of both sellers and buyers are presented as a set of virtual currency exchange rates (e_{xy}). The computation of a set of e_{xy} at a particular time point (i.e. Pareto exchange point) is given by a VMX Exchange Rate Algorithm (VERA) [3], stipulated in either a sell-lead (1a) or a buy-lead (1b):

$$\begin{cases} e_{c_1 o} \sum_{x=c_1}^{c_n} s_{c_1 x} = \sum_{x=c_1}^{c_n} e_{xo} \cdot s_{xc_1} \\ e_{c_2 o} \sum_{x=c_1}^{c_n} s_{c_2 x} = \sum_{x=c_1}^{c_n} e_{xo} \cdot s_{xc_2} \\ e_{c_3 o} \sum_{x=c_1}^{c_n} s_{c_3 x} = \sum_{x=c_1}^{c_n} e_{xo} \cdot s_{xc_3} \\ \vdots \\ e_{c_n o} \sum_{x=c_1}^{c_n} s_{c_n x} = \sum_{x=c_1}^{c_n} e_{xo} \cdot s_{xc_n} \end{cases} \tag{1a}$$

$$\begin{cases} \sum_{x=c_1}^{c_n} e_{xo} \cdot d_{xc_1} = e_{c_1 o} \cdot \sum_{x=c_1}^{c_n} d_{c_1 x} \\ \sum_{x=c_1}^{c_n} e_{xo} \cdot d_{xc_2} = e_{c_2 o} \cdot \sum_{x=c_1}^{c_n} d_{c_2 x} \\ \sum_{x=c_1}^{c_n} e_{xo} \cdot d_{xc_3} = e_{c_3 o} \cdot \sum_{x=c_1}^{c_n} d_{c_3 x} \\ \vdots \\ \sum_{x=c_1}^{c_n} e_{xo} \cdot d_{xc_n} = e_{c_n o} \cdot \sum_{x=c_1}^{c_n} d_{c_n x} \end{cases} \tag{1b}$$

where $C = \{c_1, c_2, ..., c_x, ..., c_y, ..., c_n\}$ is a set of virtual currencies of many virtual worlds; c_o is an intermediate virtual currency for computational purpose; s_{xy} refers to supply s units of currency c_x to convert back *certain units of* c_y virtual currency at exchange rate e_{xy} (i.e. c_y per c_x). d_{xy} refers to demand d units of currency c_x to pay out *certain units of* c_y virtual currency at exchange rate e_{xy}.

In VERA algorithm, when sell-lead (1a) is adopted, all virtual currency demands are converted to virtual currency supplies. That is, every virtual currency user has known virtual currency supply units but does not know how many units will be traded back. The trade-back units of demanded virtual currency c_y is determined by the exchange rate e_{xy} that is computed after posting the supply units s of the supplied virtual currency c_x. Similarly, it is the same for adopting buy-lead (1b) for e_{xy} computing. It shall be noted that this paper only adopts sell-lead (1a) for all purposes.

The unknown trade-back units of virtual currency c_y with the known units of virtual currency c_x generates a significant problem: some virtual currency exchange requestor might not satisfy the trade-back units of c_y because they think the exchange rate is lower than their original expectation such that each unit of his/her virtual currency c_x trades back less units of a demanded virtual currency c_y. If a currency exchange requestor has a minimum acceptable rate (MAR) $e'_{xy} = c_y y'/1c_x$ used as an expectation, and if the trade-back units y of c_y is less than the units y', i.e. $e_{xy} < e'_{xy}$, the *expectation problem* occurs.

When the expectation problem happens, virtual currency exchange requestors may regard any exchange rates of $e_{xy} < e'_{xy}$ = MAR as unfair exchange rates. The units of c_x in $e_{xy} < e'_{xy}$ = MAR are most likely to be withdrawn from the recommended exchange transactions. Under this circumstance, the overall Pareto equilibrium is then broken. To continue the maintenance of Pareto equilibrium to achieve fairness, the expectation problem must be solved.

B. Expectancy Theories

Collins' Dictionary defines that "your expectations are your strong hopes or beliefs that something will happen or that you will get something that you want". Expectation has been widely studied in many research fields such as economics, psychology, organizational behavior, consumer psychology and behavior, and game theory [5][8][10].

1) Vroom's Expectancy Theory

Vroom's expectancy theory [11] is about the motivation and effort of performing a task. It states that an employee's motivation to complete a task is influenced by their personal views regarding (1) the probability of completing the task and (2) the possible outcome or consequence of completing the task. The motivation is a function of the relationship between:

- Expectancy. Perceived probability of effort reflected in performance.
- Instrumentality. Perceived probability that performance will lead to particular outcomes / rewards.
- Valence. Strength of preference for a given outcome.

where force (F) or effort of motivation equal to expectancy × valence.

This theory can basically explain why virtual money exchange requestors want to set a minimum acceptance rate (MAR) before they obtain actual virtual money exchange rates. However, it cannot explicitly tell how to process those virtual money supplies associated to MAR.

2) Porter and Lawler's Expectancy Model

Porter and Lawler's expectancy model [7] is based on Vroom's expectancy theory. They agree with Vroom's statement on individual's motivation to complete a task is affected by the reward they expect to receive for completing the task. They recognize:

- Intrinsic and extrinsic rewards.
- Individualized preferences for rewards.
- Effort-performance link is a function of personal attributes fit between perceptions and demands of role.

By these recognitions, they provided an improved expectancy model, shown in Fig. 1.

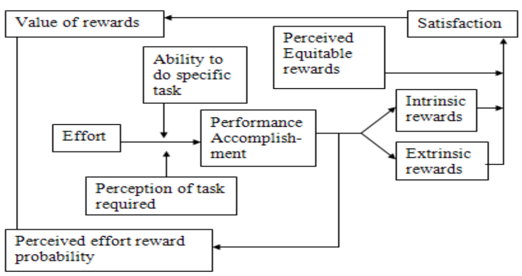

Figure 1. Expectancy model of Porter and Lawler [7]

In this model, rewards are explicitized as intrinsic and extrinsic rewards. They can be measured with satisfaction value by comparing with the perceived equitable rewards.

Applying this expectancy model, we further explain why virtual money exchange requesters withdraw exchange requests based on the comparison mechanism between rewards and perceived equitable rewards. It also state that individuals must have ability to do specific task.

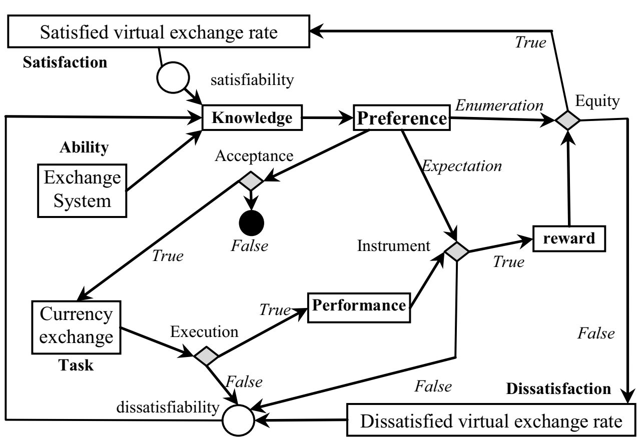

Figure 2. A formal expectancy model

III. A FORMAL EXPECTANCY MODEL

In this section, we combine Vroom's expectancy theory and Porter and Lawler's model to propose a new formal expectancy model to computationally explain what expectations are and how they are achieved. This model is shown in Fig. 2. By this model, we can have a theoretical foundation to solve the expectation problem not having been solved in VMX Theory, which is introduced in Section 2.A.

This model states as follows: (1) *Task* of obtaining a satisfied virtual exchange rate is a probability of *Acceptance* based on the ability of existing virtual exchange systems, personal knowledge, prior satisfaction experience and personal preferences. (2) *Performance* of achieving Task for a fair virtual exchange rate (called *performance rate*) depends on the probability of *Execution* of the existing virtual money mechanism (e.g. VMX systems). (3) *Reward* of a performance is an individually satisfied virtual exchange rate (called *reward rate*) passed from performance rate based on a personal *Instrument*, which is a probability of satisfying a personal preference in terms of a minimum acceptable virtual currency exchange rate (MAR). (4) *Satisfaction* means that every participant involving in virtual money exchanges at a time has a Reward (obtained a reward rate). Such a set of reward rates satisfying all is called a set of *satisfied rates*, which requires a kind of *Equity* in which all feel fair in virtual money exchange. Formally, terms of this model can be defined as follows:

Definition 1 (*Knowledge*). Knowledge is an informational or procedural object, which does not need to be justified as true.

Definition 2 (*Preference*). Preference is a set of belief rules subjectively formulated by an individual based on their personal knowledge and the perception of the world.

Definition 3 (*Expectation*). Expectation is a belief rule in the Preference set, which states that a reward shall be no less than a constant, such that: *Expectation* ::= (*Reward* ≥ *Constant*).

To simplify the model description, other terms of the model are defined in Table 1 in functional forms.

TABLE I. SOME TERMS USED IN FORMAL EXPECTANCY MODEL

Term	*Functional definition*	*Def.*
Task	*Acceptance: Preference* × *data* → *Task*	(4)
Performance	*Execution: Task* → *Performance*	(5)
Reward	*Instrument: Performance* ∩ *expectation* → *Reward*	(6)
Satisfaction	*Equity:* ∑ *Reward* → *Satisfaction*	(7)

Given *Preference* of a task and *data* of virtual currency supplies of all exchange requestors, as shown in Table 1, all results of Task, Performance, Reward and Satisfaction are computable based on the probability of Acceptance, Execution, Instrument and Equity. Based on the formal expectancy model shown in Fig. 2, there exists a theorem of satisfaction as follows to state that a satisfaction always exists.

Theorem 1 (*Satisfaction*). There exists a satisfaction in the formal expectancy model after a number of computing on tasks.

Proof. To prove that there exists a satisfaction in the formal expectancy model (Fig. 2), it must prove that there exists a probability X of satisfaction, which is no less than 1 after n times of computing.

(1) Given a time series T = 1, ..., i, ..., n, at T = i, there exists m tasks $A_{im} = \{A_{i1}, ..., A_{ii}, ..., A_{im}\}$, where $m \geq 2$.

(2) Find the probability of one task achieving a satisfaction at a time point. Let T = 1 and a single task $A_{1i} \in A_{1m}$ that is performed to achieve a satisfaction. According to formal expectancy model shown in Fig. 1, if an individual task is satisfied, the execution (E) of the task to make performance and the instrument (I) of performance to get reward must all be true. The probability of A_{1i} leading to a satisfied exchange rate (SER) by both E and I at the same time is $P(A_{1i} \rightarrow \text{SER}) = P(E \cap I) = P(E)*P(I \mid E) = 1/2 * 1/2 = 1/4$.

(3) Find the probability of all tasks achieving the satisfaction at a time. Let T = 1 and m tasks that are independently being performed at the same time. The probability of achieving a satisfaction for all m tasks is: $P(A_1 \rightarrow \text{SER}) = P(\text{Equity}) = \bigcap_{i=1}^{m} P(A_{1i}) = (1/4)^m$.

(4) Find the accumulated probability of all tasks achieving the satisfaction at all times that independently happen. Let T = 1, 2, ..., n such that $P(A_{1m}) = (1/4)^m$ at T = 1, ..., $P(A_{nm}) = (1/4)^m$ at T = n. Thus, we have an aggregate probability for n sets of independent m tasks at T = 1, 2, ..., n such that $P(A_n \rightarrow \text{SER}) = P(\text{Equity}) = \sum_{j=1}^{n} \bigcap_{i=1}^{m} P(A_{ji}) = n(1/4)^m$.

(5) Find a probability X no less than 1 for a satisfaction to happen. Let $X = \sum_{j=1}^{n} \bigcap_{i=1}^{mj} P(A_{ji}) = n(1/4)^m = 1$. We have $n = 4^m$.

Thus, we have found a satisfaction which exists after T = n times of computation such that $T = n = 4^m$. Proof finishes.

Theorem 1 confirms that a satisfaction, which meets everyone's expectations (Def. 3), always exists. This Theorem provides a theoretical foundation for designing and implementing VERA-RS algorithm that is going to propose.

IV. VERA-RS ALGORITHM

Applying formal expectancy model, this Section designs a new VMX Exchange Rate Algorithm by Reduced Supply (VERA-RS). This algorithm guarantees that every *expectation* (Def. 3) of all virtual exchange requesters at T = n will be realized, that is, the constant in terms of minimum acceptable virtual money exchange rate (MAR) shall be no larger than the Reward in terms of *reward exchange rate* (RER).

A. Assumptions, Definitions and Notations

To achieve the goal of algorithm design, VERA-RS makes a number of assumptions and definitions.

Assumption 1. Any virtual money exchange rate computed by VERA algorithm is fair without any expectation. The proof has been given by VERA algorithm [3].

Assumption 2. Information about money supply for all virtual currencies and minimum acceptable rates (MAR) is always available in practice, where money supply is represented by Sell-Lead. This assumption always holds when the VMX system [3] is accessible to all requesters R.

Definition 8 (*Virtual exchange task* - A). A virtual exchange task is a truly tested preference (Def. 4) to sell u units of currency c_x for v units of another currency c_y, making $A = u/v$.

Definition 9 (*Minimum acceptable rate* - MAR or e^o_{xy}). A minimum acceptable rate is a preferred virtual money exchange rate defined as a constant of Expectation (Def. 3) by requestor $r \subset R$, such that r is willing to sell P units of currency x for Q^o units of another currency y, making $e^o_{xy} = Q^o/P$.

Definition 10 (*Performance exchange rate* - PER or e_{xy}). A performance exchange rate is a fair virtual exchange rate without expectation computed at a time point t = k (k ≠ 0) at a Pareto exchange point, defined in VERA algorithm [3], such that an exchange requester is willing to sell P units of his/her currency x for Q units of other's currency y, making $e_{xy} = Q/P$.

Definition 11 (*Reward exchange rate* - RER or e'_{xy}). A reward exchange rate is a fair and individually expected virtual exchange rate computed from a performance exchange rate at the condition of an individual expectation (Def. 3), such that:

- RER ::= PER | MAR ≤ PER, or
- $e'_{xy} ::= e_{xy} \mid e^o_{xy} \leq e_{xy}$.

Definition 12 (*Satisfied exchange rate* - SER or e''_{xy}). A satisfied exchange rate is a fair and expected virtual exchange rate out of all reward exchange rates at a time in the condition that every reward exchange rate is no less than minimum acceptable rate, such that:

- SER ::= {RER | MAR ≤ RER}
- $e''_{xy} = \{e'_{xy} \mid e^o_{xy} \leq e'_{xy}\}$.

Based on the above assumptions, definitions and notations, VERA-RS computes a set of satisfied exchange rates to all.

B. M-Stage and N-Phase Three-Level Computing Framework

VERA-RS computes a set of satisfied exchange rates on a novel computing framework, such that there are m ($m \geq 0$) computing *time stages* of T = 1, ..., m, and each time stage has n time phases of T_m = 1, ..., n. At a particular time phase $T_j = i$, there is a three-level computation model to perform a given set of virtual money exchange tasks Ai to find a satisfaction, such that there is a set of tasks finally achieves satisfied exchange rates (SER).

1) A three-level computing model

A three-level computing model is proposed to test whether there exists a set of satisfied exchange rates at time phase $T_1 = 1$ for a given set of tasks A_{1k}. To achieve a set of satisfied exchange rates (SER), three computing levels of performance level, reward level and satisfaction level are provided.

- *Performance level*. It tests whether there exists a set of performance exchange rates (PER) for every task

$A_{1i} \subset A_1 = \{A_{11}, ..., A_{1k}\}(|A_1| \geq 2)$ at a time phase $T_1 = 1$ for every requester $r \subset R$. In this test, VERA algorithm [3] is applied to find performance exchange rates PER.

- *Reward level*. It tests whether there exists a set of reward exchange rates (RER) for every performance exchange rate (PER) of all tasks A_1 such that PER is no less than minimum acceptable rate (MAR) at time phase $T_1 = 1$.
- *Satisfaction level*. It tests whether every task $A_{1i} \subset A_1$, A_{1i} has a reward exchange rate (RER) that is no less than MAR. If the tests are true for all tasks A_1 at $T_1 = 1$, reward exchange rates RER are also satisfied exchange rates SER.

The three-level computing model provides a test of whether there exists a set of satisfied exchange rates (SER) for all tasks at a given time phase $T_1 = 1$. If SER is achieved, the algorithm stops computing.

2) Phase-wise RS method

The three-level computing model tests whether a set of satisfied exchange rates (SER) can be found at a given time phase $T_1 = 1$. A problem is that we cannot guarantee that SER could be found at a single time phase.

To solve the problem, a new method of reducing virtual money supply by excluding failed tasks in a new time phase (shortly *phase-wise RS method*) is proposed. This method clips those failed tasks FA_i (together with their corresponding virtual money supply) during SER test in the three-level computing model at $T_1 = 1$, and re-summarize the virtual money supply about the new task set of $A_{1+1} = A_1 - FA_1$ for $T_1 = 2$.

At $T_1 = 2$, the task set A_{1+1} is again tested to find the satisfaction of SER. This process continues until the set SER is found at A_{1+i} in time phase $T_1 = n$ or stops when $| A_{1+i} | < 2$. If SER is achieved at $T_1 = n$, the algorithm stops computing.

3) Stage-wise reset method

When a task set $| A_{1+i} | < 2$ at time phase $T_1 = n$ and the set of satisfied exchange rates SER is still not found, this situation signifies that the above-mentioned phase-wise RS method cannot find a set of SER for virtual money exchange transactions. To resolve this problem, this paper further proposes a *stage-wise reset method*, which states that when a phase-wise RS method fails, the systems must reset task set by accepting a new set of virtual money exchange requests as a new task set. This new task set again experiences three-level computing model and phase-wise RS method to find satisfied exchange rates (SER) at $T_2 = 1, 2, ..., n$.

If at time stage T_2 still cannot find SER, the process continues until T_m. Based on Theorem 1, a satisfaction, i.e. a set of satisfied exchange rates (SER), will be found by guarantee at most at T_m, where m is the number of stages.

The m-stage and n-phase three-level computing framework is fundamental for designing VERA-RS algorithm that finds satisfied exchange rates (SER). The mathematical foundation of this framework is the law of large number in probability such that there is a probability of obtaining SER during many trials of phase-wise reduced task sets and stage-wise reset task sets. Economically speaking, it is based on the belief that demand and supply will finally find an equilibrium at market force. The lower probability of achieving SER may drive exchange requesters to alter their minimum acceptance rates (MAR) and change their supply volumes. In VERA-RS algorithm design based on the above-mentioned framework, a reminder will be issued to all exchange requesters, saying "Your minimum acceptance virtual exchange rate is set too high. Please adjust it". This reminder will force exchanger requesters to aware the market force. Nevertheless, how exchange requesters will alter their MAR and supply volumes at the market force is beyond the purpose of this paper though it is an interesting topic for further research.

C. Computation of Satisfied Exchange Rates

In this subsection, VERA-RS algorithm is designed and structured in two cycles of stage-wise task set reset computing and phase-wise task set reducing computing. In stage-wise computing cycle, exchange requesters can change and reset their MAR, new selling currencies and new selling amounts. However, in phase-wise computing cycle, requesters do not allow to change MAR, selling currencies and selling amounts. In any next phase-wise computing phase upon last failed SER test, VERA-RS algorithm reduces selling amounts (i.e. virtual money supply) by excluding those exchange tasks in terms of exchange transactions that cannot achieve reward exchange rates. A set of satisfied exchange rates (SER) are finally achieved in a three-level computing model of a certain stage and certain phase, depending on the actual situations of MAR, supply currencies and supply amounts.

Fig. 3 provides a pseudo code of VERA-RS algorithm for the detailed understanding of the algorithm design.

```
StartNewStage(){
  MakeNewTask(tasks, MAR);
  StartNewPhase(){
      // Three-level computing model
      if VERA(tasks) then {
        PER ← VERA(tasks);
        if PER ≥ MAR then RER ← PER
        else {
          tasks := reducedTasks;
          if |tasks| ≥ 2 then StartNewPhase()
          else {
              Sleep(1_hour);
              StartNewStage();
          }
        }
      }
      else Exit() // Malfunction of VERA systems.
  }              // Phase-wise computing by reducing tasks.
}                // Stage-wise computing by resetting tasks, MAR.
SER ← RER;   // Find satisfied exchange rates.
```

Figure 3. VERA-RS algorithm

The characteristic of VERA-RS algorithm is that it automatically generates satisfied virtual currency exchange rates by reading exchange requesters' stored information about exchange tasks such as selling currency type, selling amount, MAR and other information. It inherits the feature of VERA algorithm [3] that maintains fairness of virtual money exchange between exchange requesters. Besides, it also satisfies the individual expectations of exchange requesters on virtual currency exchange rates.

V. CONCLUSION

This paper has proposed a VERA-RS algorithm that extends the previous VERA algorithm [3] to dynamically generate satisfied virtual currency exchange rates that are not only fair to all participated exchange requesters but also meet the personal expectations on virtual currency exchange rates of all exchange requesters. The VERA-RS algorithm is designed based on a novel formal expectancy model, which theoretically proves that there exists a set of satisfied virtual currency exchange rates. Based on this model, an m-stage and n-phase three-level computing framework is proposed as the design framework of VERA-RS algorithm. Further based on this framework, VERA-RS algorithm is designed in detail to realize the goal of achieving a set of satisfied virtual currency exchange rates.

This paper has the following contributions. Firstly, it has first time resolved the expectation problem that exchange requesters expect the systems-generated virtual currency exchange rates to be higher than their minimum acceptable rates (MAR), which has not been solved in the previous work of VMX systems [3]. Secondly, it has developed a novel formal expectancy model, which proves that all individual expectations of exchange requesters can be satisfied. Thirdly, it has proposed an m-stage and n-phase three-level computing framework for designing the new algorithm of VERA-RS. Fourthly, it has designed VERA-RS algorithm in detail based on the formal expectancy model and the n-phase three-level computing framework to achieve the goal of finding satisfied virtual currency exchange rates.

The newly designed VERA-RS algorithm is important and has many implications on virtual world study and electronic commerce. First, it provides a tool of enabling virtual trade across virtual worlds through a cross-world money exchange system. Second, it provides a mechanism of transferring virtual wealth between virtual worlds and thus becomes a media of protecting virtual wealth accumulated in virtual worlds. Third, it enables fair trade of virtual currencies between virtual worlds. Fourth, it satisfies personal expectations on virtual currency exchanges and provides the freedom of deciding whether to exchange other virtual currencies or not.

While this paper provides a solid design of VERA-RS algorithm to achieve satisfied virtual currency exchange rates. Future work is still needed in the aspect of studying the virtual market force that might affect the modification of minimum acceptable rates (MAR), supplied currencies and supplied amounts, which will further affect the efficiency of obtaining satisfied virtual currency exchange rates.

Currently, a VERA-RS based virtual currency exchange simulator is in development by the research group of the authors for making experiments on virtual currency exchange behaviors and will be released in soon.

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