Exploring Agent-Based Methods for Activity Network Prediction in Real Time Gross Settlement (RTGS) Based on Clearing House

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Summary
This paper presents an exploratory agent-based model for activity network prediction in RTGS based on clearing house. The settlement process, which is developed, is managed by clearing house. The sufficiency values are fulfilled by other banks that are participant banks at clearing house. At this paper, the participant banks are depicted by node. Decision to fulfill settlement process from other banks is done by forming activity network. At this paper, the activity network is depicted by edge. The forming of activity network is depending on information from agents. This paper adopts decentralization paradigm for modeling activity network. The result of this research indicates that amount of nodes are same, more of activity networks between banks hence are more network identified. While degree between 0 to 2, the smaller difference of the health bank level, that will forming network, the greater network are identified. For degree which more than 2, no network are detected, this condition is caused of fixed point behavior. Testing with $\lambda = 0.7$, x starts with degradation drastically towards stable value come near 0. $\lambda = 1.8$, x starts with degradation drastically value towards stable value, but stability value still not yet come near 0. $\lambda = 2.9$, x oscillates about fixed point and converges. While $\lambda = 3.9$, x starts to oscillate.

Key words:
RTGS, clearing house, settlement, activity networks, agent

1. Introduction

RTGS is a system that streamlines the settlement of large-value transactions between banks and other financial institutions. Instead of moving physical amounts of cash, the banks transfer funds electronically. When one bank transfers money to another, the funds are immediately credited to the second bank and debited to the first. In general, the settlement of interbank funds transfers can be based on the transfer of balances on the books of a central bank (i.e. central bank money) [1]. The possibilities of payment processing, when the sending bank does *not* have sufficient covering funds in its central bank account, are rejected, centrally queued and settled with central bank credit [2].

In RTGS systems, queues are most commonly generated when sending banks do not have sufficient covering funds in their central bank account. If the queued transfers did not settle, the receiving bank could face a liquidity problem. Particularly if this occurred close to the end of the day, it might then be difficult for the bank to raise the liquidity it needed from alternative sources. Base on this problem some researches try to increase liquidities value at critical conditions

An agent-based model of crisis simulation for a simplified RTGS is presented by *Luca at al* [3]. The model's predictions approximated the macro-features of reality, shown the sequential effects of an unexpected negative shock affecting a participant [3]. But this research had not analyzed the behavior of fixed point at data that was influence the stability.

In this paper, we propose to develop a graph mining to exploring agent-based methods for activity network prediction in RTGS payment system based on clearing house. This research models an activity network in the graph and models the data by entangling variables having an effect on find relationship between banks. Graph which is yielded at graph mining is analyzed and connected by behavior of the fixed point at the data model for identify the critical condition, that cause the systemic risk. The Result of the data modeling and activity network modeling are tested in the serious game.

The rest of this paper is organized as follows. The theoretical consideration that supports the implementation method is described in section 2. The proposed model for bank network is discussed in section 3. Section 4 gives the bank network analysis. Finally conclusions are given in section 5

2. Theoretical Consideration

In this part is described of the theory that support of the activity network modeling of an exploratory agent-based model for activity network prediction in RTGS based on clearing house. These theories are theory graph, mechanism of RTGS and approach based on agent.

2.1. Graph

Activity network between banks for settlement process are represented in graph. Graph consists of a group of vertices

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(V) and edges (E), that can be written by $G = \{V, E\}$. Vertices in this research represent a bank, while edges represent an activity network. Edge ($e \in E$) is a group of relationship between two vertices from a group of V [4]. For example Vertices, $V= \{ v_1, v_2, v_3,, v_4, v_5\}$, and Edges, $E= \{ e_1, e_2, e_3, e_4, e_5\}$, can be written by $E= \{(v_1, v_3), (v_3, v_5)\}$ if $e_1= (v_1, v_3)$ and $e_2= (v_3, v_5)$. This example equals to activity network that consists of five banks with label v_1, v_2, v_3, v_4 and v_5. Activity network, that is formed, are v_1 and v_3 also v_3 and v_5 as shown in Fig. 1

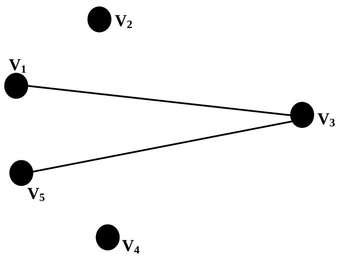

Fig. 1 A graph with five labeled nodes and two edges

2.2. Real Time Gross Settlement

In modern exchange economies, the smooth functioning of economic activity is heavily dependent on the reliability and the efficiency of payment systems. Cash transactions are steadily diminishing; consumers and firms generally settle their obligations through banks or other financial intermediaries, by means of instruments such as checks, money orders and electronic transfers [5]. The intermediaries themselves initiate numerous payment flows for their own treasury operations or for other reasons. The basic functioning of an RTGS environment as shown in Fig. 2.[3].

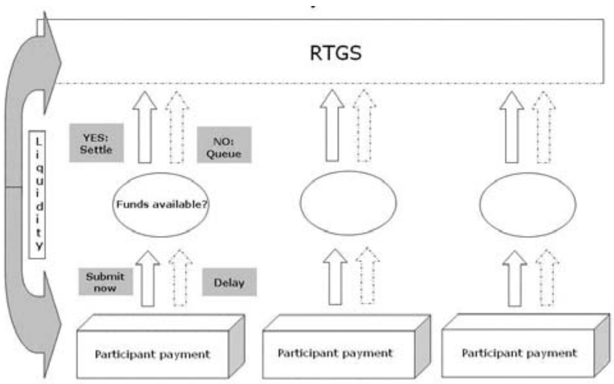

Fig. 2 Basic functioning of an RTGS environment

Transaction mechanism in RTGS as shown in Fig. 2 started with remitting participant orders the payment transaction to center of management of RTGS system in central bank for settlement process. Payment information will be continued automatically and electronics to receiver participant if settlement process run success. Success or failure of settlement process depends on sufficiency of sending bank balance value in central bank. This condition is caused of system RTGS only allowing participant credit other participant. If it was the rule of the game, hence RTGS participant bank must know the sufficiency of balance in central bank.

According to the actual and expected availability of each category of resources, banks make the strategic decision as whether to submit a payment promptly or delay it, thus affecting the overall time pattern of flows in the RTGS. In this respect, banks continuously face a trade-off between liquidity costs and delay costs. By releasing payments timely, banks satisfy customer and counterparty needs and benefit from a sound reputation, but they can incur high liquidity costs insofar as they need to borrow from the money market or the central bank. On the other hand, banks can play on the dynamics of the money market more effectively by choosing to delay payments, at the expense of increased systemic risk and reputation uncertainty[2].

2.3. Bank Network with Agent-based Approach

A well-established line of research uses traditional simulation techniques for the analysis and monitoring of settlement systems, with a view to the containment of typical credit, liquidity, and operational risks. Different tasks can be performed with different input data and simulation methods: historical data of payments submitted by banks can be used for "what if" analyses under different settlement mechanisms, while stochastic inputs can be used either for theoretical studies or for models aimed at extrapolating the consequences of particular behavioral assumptions on small-scale settings [3].

Along these theoretical lines, the Bank of Finland pioneered the construction of large-scale simulation models for settlement systems by building an ad hoc algorithm, where a deterministic stream of payments is accepted as an input and dealt with in a centralized manner under different hypotheses on the operating rules. Bank behavior is taken as given, or is made able to evolve in a predetermined manner. At present, the Bank of Finland simulator is widely used to evaluate the functioning of large-value payment systems under stressful conditions [6].

Compared with these earlier experiences, agent-based modeling has been introduced in this field only recently. Banks are seen as agents acting independently, and the system evolves as a result of their interaction. In some cases, intelligent adaptation to changing scenarios is allowed [7].

The method appears to be particularly suitable for the problem for three reasons [8]. First of all, it works well in terms of micro-foundations: in the short run, and especially where overnight activity is concerned, the behavior of commercial banks and of the central bank can be realistically described in terms of simple and consistent rules governing relatively straightforward decisions. The set of available strategies can be described in the language of game theory and translated into algorithms with ease.

Secondly, agent-based models take the temporal dimension onboard fully; faced with a highly parallel, highly complex world, this feature is essential. Given a flow of due payments, banks mainly choose in which order to submit these payments to the system and how to obtain the liquidity necessary to meet obligations, subject to known constraints. Domino effects arising after a disruption can be properly described only if time is represented with a sufficient level of precision.

Last but not least, the flexibility of the agent-based approach constitutes an advantage when dealing with remarkably fast-changing environments, such as the financial one. Payment systems evolve; the banking sector consolidates, both domestically and internationally; some types of bank disappear, others gain prominence; occasionally, entire countries join a given system or withdraw from it; new financial instruments emerge; rules may change, at least partly. Traditional simulations need to be recalibrated, partly or entirely, whenever one of these discontinuities occurs, as they often involve new analytical identifications of equilibrium. On the contrary, agent-based models can be adapted efficiently with a relatively small number of alterations.

3. The Proposed Model for Bank Network

Bank activity network is a complex relationship. These relationships sometime strengthen but sometime weaken to purpose of finance as effect of position, individual behavior and environmental influence. In this paper applies letters notations (A, B, C, D, E F,…) to represent nodes or participant bank in clearing house, while the numeral notation (1, 2, 3, 4,…) are applied for represent the edges or activity networks.

3.1 Activity Network Modeling

In general, The mechanism of RTGS transaction is done by the way of remitting participant sends a message of payment transaction to center of management RTGS system located at central bank for settlement process. The settlement process, that our proposed at this paper, is managed by clearing house.

The mechanism at clearing house is a consignor client sends a message of transaction through remitting bank, that having canal at clearing house, then continue to receiver client through receiver bank as shown in Fig. 3.

In general, settlement process depends on sufficiency of remitting bank account balance in central bank. Assess sufficiency at this research is fulfilled from other banks, that are participant bank at clearing house, or borrowed from money market that provided by clearing house. Decision of accomplishment from some other banks or from money markets depends on information of agents on the clearing house.

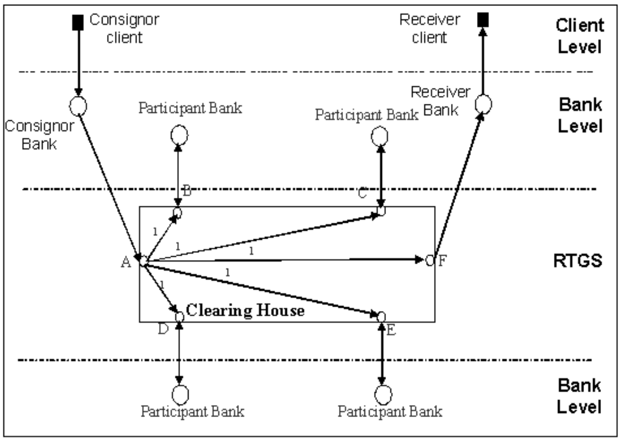

Fig. 3 The proposed model for RTGS based on clearing house

Activity network prediction, in general, is applied in two separate method (but complementary) that are relational analysis method (or topological analysis) and fitur analysis [9]. The first method aims to test unbalance graph structure that tending to balance state. The second method more checks contents of communications between individuals to looking for interest of enthusiasms. This research concentrates on the first method that predicting activity network by using graph that is formed by agents. The graph theory purely of course will get small accuration if compared by using combination both graph theory and content analysis, but usage of graph theory purely stills competent for analyzing network without content.

Network predicting technique applies metric to form the new activity network. The activity network will be formed at the point that having higher angle than lower angle [10]. The angle at this model is related to analysis rate of return condition of health bank that is applied CAMEL method [11] of two banks which will be form activity network.

The old research that checking the network predicting for example is Popescul and Ungar [12] check citation prediction system apply structural logistics regression method. This research predict pattern query network at relational database, including join, selection and aggregation. Taskar et all [13] apply relational model Markov for studying pattern of hyperlink group and web page transitivity. These prediction system include node attributes (example: web page text) which is additional relational fitur. Popescul and Ungar increase network prediction from document by using clustering [14]. This research increase accuration model average 4%. Zhou and Scholkopf do approach of three problems of Graph related that are classification, ranking and network prediction. This research define equation of discrete at Graph, then shift regularization from continue case to data Graph. This research was not examination empirically but modeling in mathematics [15].

Network prediction at this model is applied to determine new activity network in RTGS based on clearing house to fulfill settlement process. For example remitting bank A will fulfill sufficiency value by forming graph starts from F then B continue to C, D and E ($A\rightarrow F\rightarrow B\rightarrow C\rightarrow D\rightarrow E$) or $A\rightarrow F\rightarrow C\rightarrow B\rightarrow D\rightarrow E$ or $A\rightarrow F\rightarrow D\rightarrow C\rightarrow B\rightarrow E$ or other pattern possibility until the sufficiency value is fulfilled based on information intelligent distributed agent as shown in fig. 4.

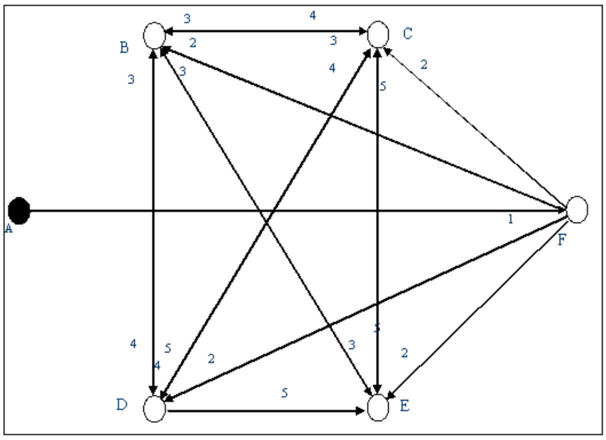

Fig. 4 Probability graph that formed of 6 participant banks

Dominant theme in artificial intelligence community in this time is distributed intelligence or decentralization of decision making. Resnick decrypted decentralization as mode to understand a complex system like an ant colonies, flocks of birds, traffic, economic markets, evolution and immune systems [16].

This research adopts the decentralization paradigm for modeling activity network system. The principal component of this system are adaptive agents consisting of five agents that are Saving agent, Reserves agent, Loan agent, Deposit agent and Money Transfer agent as shown in fig. 5.

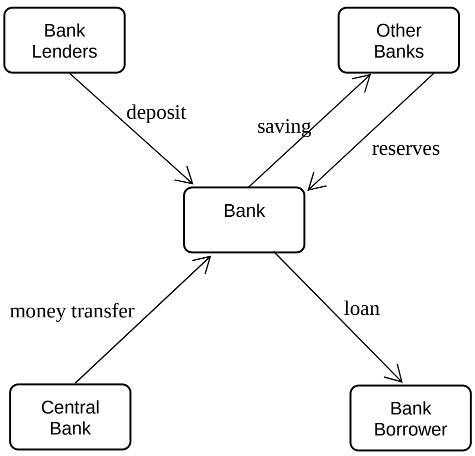

Fig. 5 Decision of bank based on 5 agent information

Saving Agent give information concerning advantage that saving his money to other banks based on health analysis two banks. Reserves Agent give information of advantage that taking reserve his money in other bank based on health analysis two banks. Loan Agent gives information concerning advantage that loan his money to other bank based on health analysis two banks. Money Transfer Agent gives information concerning advantages that apply the deposit in Central Bank. Deposit Agent give information concerning advantage that borrowing some money from other banks based on health analysis two banks.

3.2 Data Modeling

Data modeling entangles attribute analysis for finding relationship between banks. Activity network prediction, which will be formed, entangles the relation of variable y (two nodes will be formed new activity network depend on value of variable b and variable x) as shown in Eq. (1)

There are some technique for finishing these problems, for example linear regression, logistics regression, network Bayesian and clustering. Hosmer and Lemeshow recommend logistics regression as appropriate method for binary data [17]. The logistics regression as shown in Eq. (1).

$$y = b_0 + b_1 x_1 + b_2 x_2 + \ldots + b_n x_n \quad (1)$$

x_1, x_2 ... , x_n in this paper are estimator variable, in this case is bank which will be formed activity network. Coefficient b_0, b_1, ... , b_n are carrying capacity of area, in this case is health analysis two banks that is applied CAMEL method (capital, assets, management, earnings and liquidity) [11]. Hosmer and Lemeshow was map X_n to X_{n+1} as shown in Eq. (2) [17].

$$X_{n+1} = \lambda X_n (1 - X_n) \quad (2)$$

Behavior of X_n , if it moves with small distance from fixed point will be yield X_{n+1} that condition can know from derivative of fixed point that is $\frac{dX_{n+1}}{dX_n}$ with equation as shown in Eq. (3).

$$\frac{dX_{n+1}}{dX_n} = \lambda (1 - 2X_n) \quad (3)$$

The fixed point at $Xn = 0$ is $\frac{dX_{n+1}}{dX_n} = \lambda$. The fixed point at $X_n = \frac{\lambda - 1}{\lambda}$ is $\frac{dX_{n+1}}{dX_n} = 2 - \lambda$. Slope in the two fixed points,

$$X_n = \frac{\lambda - 1}{\lambda} \quad \text{and} \quad \frac{dX_{n+1}}{dX_n} = 2 - \lambda \quad \text{show that:}$$

1. λ in the $0 < \lambda \leq 1$ range, fixed point is $X_n = 0$ (attractor),
2. λ in the $1 < \lambda \leq 2$ range, fixed point is $X_n = \frac{\lambda - 1}{\lambda}$,
3. λ in the $2 < \lambda \leq 3$ range, slope of the fixed point is negative and X_n oscillate around fixed point and convergent,
4. λ in the $3 < \lambda \leq 2$ range, fixed point starts oscillation

4. Bank Network Analysis

This part checks the condition of artificial payment system for settlement process with forming activity network between banks. Activity network is formed from journey information of 5 agents (Saving Agent, Reserves, Agent, Loan, Agent, Deposit Agent and Money Transfer Agent). Network is calculated globally in the graph

Each agent move at random from bank which require settlement process towards neighbor banks with forming activity network. The purpose of movement is settlement process. Activity network prediction at this research relate to small graph that is formed. This method is applicable at the big graph in the same way; depend on the provided memory measure. The pseudo code of activity network as shown in following.

```
algorithm graph mining
input numbanks, useractnet, healthbank;
input numSA, numRA, numLA, numDA, numMTA;
output generate_graph;
/* determine the number of activity network by
looping through each neighbour bank*/
//extracting the number from index file
for every activity banks network in Graph do
    n = numbanks{i};
    actnet = useractnet {i};
    for every actnet in Graph do
            l=metaindex(n(j)-2);
            while (dataindex(l, n)==n(j))
    if (dataindex(l, actnet)== actnet(k))
             m =dataindex(l, numgraph);
             numgraphs = numgraphs+m;
             end while
             if (l+1 > length(dataindex))
             break;
     end for
     l = l+1;
end for
```

This research propose calculation graph locally. Graph identical is yielded with partner cooperation in around, network which calculated apply network with small radiuses. Calculation node with expected small radiuses requires point of slimmer, so that will be quickening process. Example of using Graph by 6 nodes, 7 edges and degrees 1.8 as shown in fig. 6.

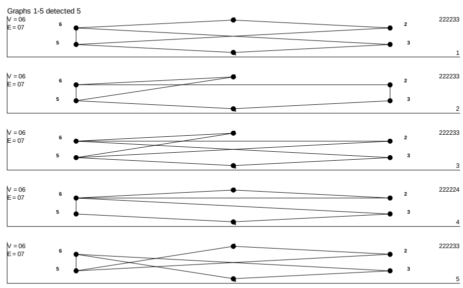

Fig. 6 Activity network prediction apply graph mining for 6 nodes, 7 edges and 1.8 degrees

Examination result applies amount of node 6 and amount of edges and degrees vary as shown in Table 1. Tables 1 indicates that with amount of node are same, ever greater edge that given (activity network between banks) hence is ever greater graph are identified. Examination applies degree between 0 until 2 that smaller degrees are ever greater graphs are identified. Examination applies degree more than 2 there are no graphs identified.

Behavior of fixed point with various of λ value, take some data according to data models, that are $0 < \lambda \leq 1$, $1 < \lambda \leq 2$, $2 < \lambda \leq 3$ and $3 < \lambda \leq 4$, yield graph as shown in Fig. 7 (λ = 0,7), Fig. 8 (λ = 1,8), Fig. 9 (λ = 2,9) and Fig. 10 (λ = 3,9). Abscissa depict amount of iterations, while coordinates depict amount of fixed points populations. Input parameters at this research are initial value (x_0) and λ value.

Table 1: Examination result of 6 nodes with various edges and degrees

Edge	Degree	Graph	
		Detected	available
5	0,7	9	15
6	0,7	15	21
7	0,7	20	24
8	0,7	22	24
5	1,8	0	15
6	1,8	2	21
7	1,8	5	24
8	1,8	11	24
5	2,9	0	15
6	2,9	0	21
7	2,9	0	24
5	3,9	0	15
6	3,9	0	21
7	3,9	0	24

Fig. 7 indicates that by using λ = 0.7, x values start with degradation drastically from initial value towards stable value come near 0. This condition shows concordance between data model and graph mining where are ever greater edge that given (activity network between the banks) hence is ever greater graph are detected.

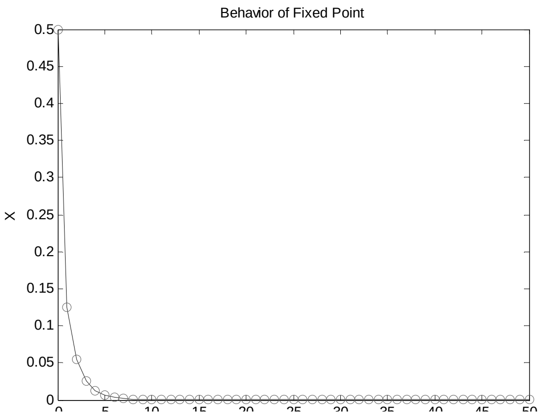

Fig. 7 Behavior Of Fixed Point at λ = 0.7

Fig. 8 indicates that by using λ = 1.8, x values start with degradation drastically from initial value towards stable value but stability value still not yet come near 0, so that still be better by using λ = 0.7. This condition show concordance between data models and graph mining where are ever greater edge that given hence is ever greater graphs are detected, but amount of graphs which are detected still be better by using values λ = 0.7.

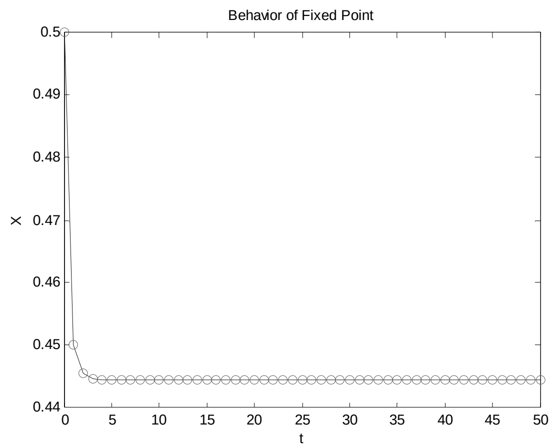

Fig. 8 Behavior Of Fixed Point at λ = 1.8

Testing by using *λ = 2.9*, *x* oscillates about fixed point and convergence. This condition show concordance between data models and graph mining there are no graph is detected from activity networks between banks (fig. 9).

Testing by using *λ = 3.9*, *x* start oscillation. This condition show concordance between data models with Graph mining there are no Graph available for detected from activity networks between banks (fig. 10).

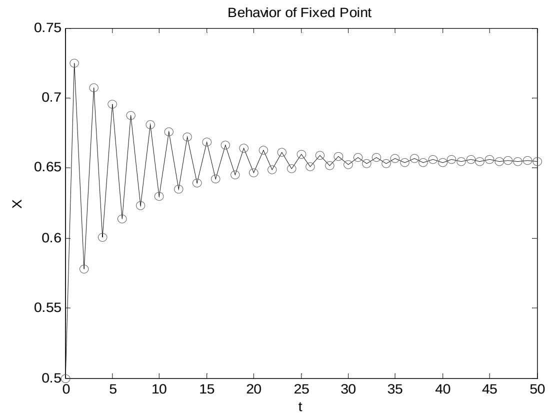

Fig. 9 Behavior Of Fixed Point at λ = 2.9

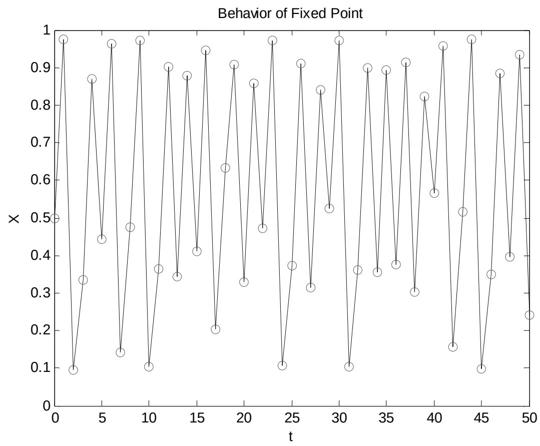

Fig. 10 Behavior of Fixed Point at λ = 3.9

The serious game for simulate banks activity network to fulfill sufficiency of settlement process at RTGS based on clearing house with exploring agent-based method as shown in Fig. 11.

Fig. 11 indicating agents consist of five types that are Saving Agent, Reserves Agent, Loan Agent, Deposit Agent and Money Transfer Agent but they are looked at homogeneous. They move at random from banks which require settlement process towards neighbor's banks for forming activity network. Simulation at Fig. 11 shows that are 4 participant banks form the activity network with bank which require settlement process.

Fig. 11 Simulation of bank network for settlement process

5. Conclusion

The result indicates that amount of node are same, more of activity networks between banks hence are more network identified. While degree between 0 to 2, the smaller difference of the health bank level, which will forming network, the greater network are identified. While for degree which more than 2 no is detected.

Behavior of fixed point with experiment by using λ = 0.7, x value starts with degradation drastically from initial value towards stable value come near 0. Experiment with $\lambda = 1.8$, x starts with degradation drastically value towards stable value, but stability value still not yet come near 0. Testing with $\lambda = 2.9$, x oscillates about fixed point and converges. While Testing with $\lambda = 3.9$, x starts to oscillate.

The examination result of activity network and behavior of fixed point indicate that are relation between amount of activity network which found and behavior of fixed points. Activity network will more found if fixed point stays at stable value, on the contrary activity network will not be found if fixed point stays at condition of oscillation.

References

[1] Committee on Payment and Settlement Systems, "New developments in large-value payment systems", BANK for International Settlements 2005.

[2] Commitees at the Bank for International Settlement, "Real Time Gross Settlement System", International Financial Risk Institute, 2007.

[3] Luca Arciero, Claudia Biancotti, Leandro D'Aurizio and Claudio Impenna, "Exploring Agent-Based Methods for the Analysis of Payment Systems: A Crisis Model for StarLogo TNG", Journal of Artificial Societies and Social Simulation vol. 12, no. 12, 2009

[4] Deo, N, "Graph Theory with Applications to Engineering and Computer Science", Prentice-Hall, Upper-Saddle River, New Jersey, 1974

[5] European Central Bank, "The Use of Central Bank Money for Settling Securities Transaction", European Central Bank, 2004

[6] Baglioni, A and Monticini, A, "The intraday price of money: evidence from the e-MID market", mimeo

[7] Fioretti, G, 2005, "Financial fragility in a basic agent based model", mimeo, 2007

[8] M. BECH and R. Garratt, 2003, "The intraday liquidity management game", *Journal of Economic Theory*, 109: 198-219.

[9] Liben-Nowell, D & Kleinberg, "The link prediction problem for social networks", Proceedings of the twelfth international conference on information and knowledge management, 3-8 November 2003, pp. 556-559, 2003.

[10] Leskovec, J, Kleinberg, J & Faloutsos, "Graphs over Time: Densification Laws, Shrinking Diameters and Possible Explanations", Proceedings of the eleventh ACM SIGKDD international conference on Knowledge discovery in data mining, 2005.

[11] Saltzman Sonia B, Darcy Salinger " The Accion Camel", Accion International, 1998.

[12] Popescul, A & Ungar, "Structural Logistic Regression for Link Analysis", Proceedings of KDD Workshop on Multi-Relational Data Mining, 2003.

[13] Taskar, B, Abbeel, P, Wong, M-F and Koller, "Label and Link Prediction in Relational Data", Proceedings of the IJCAI Workshop on Learning Statistical Models from Relational Data, 2003.

[14] Popescul, A and Ungar, "Cluster-based Concept Invention for Statistical Relational Learning", Proceedings of Conference Knowledge Discovery and Data Mining (KDD-2004) , 2004.

[15] Zhou, D & Scholkopf, B, "A regularization framework for learning from graph data", Proceedings of Workshop on Statistical Relational Learning at International Conference on Machine Learning, Banff, 2004.

[16] Resnick, M, "Turtles, Termites, and Traffic Jams", Massachusetts Institute of Technology Press, Cambridge, 1997.

[17] Hosmer, DW & Lemeshow, S, " Applied logistic regression", John Wiley & Sons, New York, 1989.

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