ANALYZING THE ROLE OF MUTUAL COMMUNICATIONS IN PROJECT MANAGEMENT THROUGH AGENT-BASED SIMULATION

Masao Watabe, Takao Terano
Tokyo Institute of Technology
4259 Nagatsuda-cho, Midori-ku, Yokohama 226-856, Japan

ABSTRACT

This paper proposes an agent-based simulation model to analyze the roles of mutual communications among members of a project team. The objective of the research is to uncover the characteristics communication efficiency in a large scale and short delivery project. In order to explore the better communication ways in project management, we develop an agent-based simulation model, in which we implement a manager-leaders group as communication agents. From intensive experiments, we have found that (1) the project productivity is proportional with the communication efficiency, (2) It is effective to communicate about many issues in one chance of communication in a large scale project, and (3) in any size of projects, it is effective to take enough time for communication.

Keywords: project management, large scale, short term, communication, ABS, agent based simulation, efficiency, productivity, team size, ISBSG

INTRODUCTION

This paper proposes a novel approach to the investigation about communication processes of project members, which employs an agent-based simulation model to analyze the roles of mutual communications among members of a project team. The objective of the research is to uncover the characteristics communication efficiency in a large scale and short delivery project. In the literature, they often report that the shorter delivery period of a project causes cost-over-run and/or schedule-delay. However, few results have been quantitatively investigated. In order to explore the better communication ways in project management, we have employed agent-based simulation models, in which we implement a manager-leaders group as communication agents based on Axelrod's tag model.

From intensive experiments, we have following major conclusions: The project productivity is proportional with the communication efficiency. The larger the scale of a project becomes, the less efficient the communication becomes. It is difficult to make a delivery period of large projects shorter comparing small projects from the communication point of view. It is effective to communicate about many issues in one chance of communication in a large scale project. In any size of projects, it is effective to take enough time for communication.

The rest of the paper is organized as follows: In Section 2, we describe current issues of project management and discuss the necessity of the research. In Section 3, we survey related work. Section 4 describes the proposed simulation model and how it works.

Section 5 gives the experimental results and discussions. Finally, concluding remarks will be given.

ISSUES OF PROJECT MANAGEMENT

Project Management Institute Standards Committee (1996) defines "A project is a temporary endeavour undertaken to create a unique product or service. *Temporary* means that every project has a definite beginning and a definite end. *Unique* means that the product or service is different in some distinguishing way from all similar products or services".

In order to achieve the goal of a project, many project members of different profession gather in a project team. The major work of the project members is to adjust technical interfaces for combining many technologies into the "unique product or service".

This adjustment is made by communication among the corresponding members in a limited period, in other words, not routinely but *temporary*. The subjects of communication vary with the progress of a project. Many tasks are scheduled from the beginning of the project to the end of the project. According to the schedule, the project members change the subjects of communication. In many cases, project managers initiate this communication. In the simulation employed in this paper, agents exchange information in a limited period to adjust technical interface issues by initiation of e-mail-messages from a project manager.

The client of system integration project sometimes requires shortening delivery period of the project. In some cases, this causes cost-over-run and/or schedule-delay in a project, especially in a large scale project. As a result of such requests of the change of the time limit, the members cannot have enough communicate time each other about the project.

To shorten the delivery period in a large scale project is observed in both system integration and plant construction projects. This is a risk and major issue for all contractors related to the project management. However, this risk was not studied theoretically but discussed just as lessons learned. This is because the amount of communication in projects is too huge, especially in a large scale project, to gather communication data for quantitative investigation. Actually, most of the best practices in the literature are described only by just lessons learned not by statistical data.

Many project managers of a large scale project shortened delivery period of his or her projects unwillingly by the request of clients. However, some of them believe there is no difference between a large scale project and a small scale project in shortening the delivery period and accept shortening finally. This is because they are not informed theoretically of what impact can be made by shortening delivery project. They do not know what countermeasures should be taken in the shortened large scale projects. As the result, many large scale project end in failure. However, by using computer simulations, we can confirm the lessons learned and sometimes can clear up misunderstanding by quantitatively and theoretically.

There is no firm definition about large scale projects by regulations or by standards. However, we suppose a system integration project over 10 million US$ and a plant construction project over 100 million US$ can be said a large scale project. In this kind of large scale projects, the number of professional groups is 15 for system integration and 17 for plant construction from our experience. We think much larger scale project must have more professional groups. This number is referred to when we determine the range of parameter for simulation. Concretely speaking, the range of number of PL (Project Leader) mentioned later was set to vary from 4 to 20. This covers from an ordinary size project to a large scale project.

In order to simulate to shortening delivery period, we have made our simulation model to have a range of parameter of e-mail-message cycle namely “cycle of request” from 1 to 5. As mentioned above, the agents exchange information by initiation of e-mail-message from project manager. This can enable us to simulate the communication in shortened projects.

RELATED WORK

In this section, referring to the literature, we will explain the phenomena that the larger number of project members become, the more complicated and more frequent the communication becomes.

Brooks (1995) observed that additional members to a software development project halfway cannot work well in some cases; it will rather delay the schedule. Similar arguments are found in ISBSG (2007). They describe that the larger the number of project team member increases, the lower the productivity becomes in software development project. This means amount of communication and the increase of complexity impact on the productivity. Our experience of project management practice also supports the statements. The communication is a major work load for the members of a large scale project.

Quantitative discussions are found in ISBSG (2005). They propose the following formula to express the relation between project productivity and team size. (p.117, Table 3.0 – “Project Delivery Rate using maximum team size only”)

$PDR = C \times MaxTeam^{E}$,

Where, PDR: Project Delivery Rate (Person Hours/Function Point)

The constants of the above formula are investigates from the data of actual 622 projects:

$C = 3.799 \qquad E = 0.521.$

$(Function\ Point/Person\ Hours) = 1/(C \times MaxTeam^{E}) = 1/(3.799 \times MaxTeam^{0.521})$

$$= 0.26 \times MaxTeam^{-0.521.}$$

We will use the formula as a benchmark of our investigation by the agent-based simulation.

However, Brooks' literature is just lessons learned and is not supported by theoretical analysis. ISBSG gives us statistical data and formula about impact of team size (scale of project size) on productivity. When we discuss efficiency of communication with productivity, we have to justify the productivity is determined by efficiency of communication. In this paper, we did this by comparison with ISGSG formula.

PROPOSAL OF AGENT-BASED MODEL

In this section, we describe our Agent-Based Simulation (ABS) model.

Simulation Targets to Model Project Team Organization

An ordinary project team is organized by three levels: Project Manager (PM), Project Leader (PL) and Project Member (M) shown in Figure 1. PL is a leader of a group of Project Members for a certain professional task domain. In most cases, a PL coordinates and exchanges with other PLs about information necessary for his or her group to carry out works in the project.

The above communication is made among PM and PLs. At the same time, similar communication is made among PL and Project Members. We call the former as "First level" and the latter as "Second level". We will develop a simulation model for the "First level" in this study.

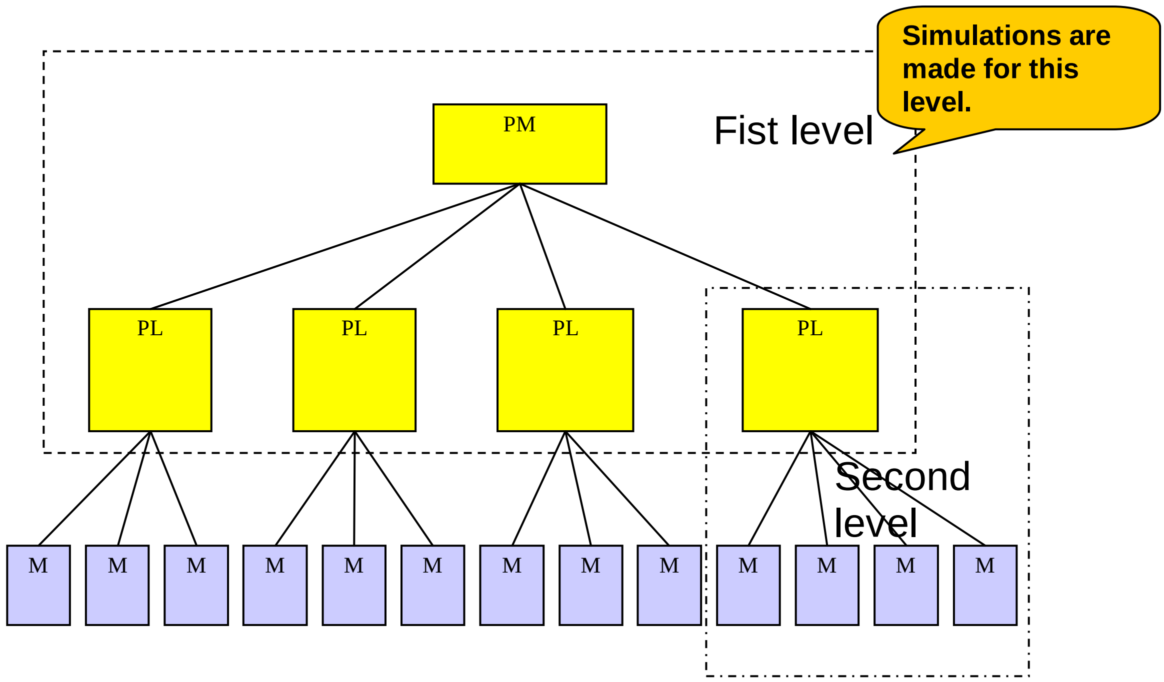

Figure 1. Part of simulation

Basic Mechanism of the Simulation Model

Axelrod's tag model is a communication model of culture transformation. In the model, he divides one area into 10 x 10 = 100 cells. One agent is located in each cell. Initially, each agent has unique combination of cultures like 78295. This represents the combination of 10 levels for 5 kinds of cultures. The agents exchange their culture with neighbouring agents which has 'similar' culture. The similarity is measured by the distance of the two character strings. Our simulation is modified from the Axelrod's tag model. The major difference is that the agents (PL) are not fixed in a cell but moving in the project room.

The basic characteristics of our simulation model are described as follows:

- We set the universe of a project as two-dimensional square space, which we call it "project room". The project room has two layers. One layer is for sending and receiving e-mail-message from PM to PLs. The other is for exchanging knowledge among neighbouring PLs. PM and each PL are located in the same cells of the two layers of the project room. PM and PLs are located randomly at the start of simulation.
- The size of project room is changed depending on the number of PLs to keep the density of population in order to avoid the impact of the density. Approximately 4 cells are provided for one PL. The end of project room is not looped.
- The PM and PLs move randomly in the project room and communicate (exchange knowledge) each other when located next cell. This simulates PLs' activities of exchanging necessary information by a meeting.
- PL is a specialist and has full knowledge (level 9) about a certain professional domain. However, PL has no knowledge (level 0) for other professional areas. If five PLs are in the project room, the combination of the knowledge is five digits like 00090 before exchanging knowledge by communication. The forth digit form the left end is 9, which shows full knowledge of his expertise.
- The number of professional areas is the same as the number of PLs.
- PM sends an e-mail-message which is requesting an action (communication) to PLs. The e-mail-messages are sent randomly from the PM prepared in advance. At the beginning of a simulation, all kinds of knowledge level are 9. After the PM send all of e-mail-messages, the simulation ends.
- PLs exchange knowledge which is about the content only of the e-mail-message sent by PM.
- The knowledge for non-expertise area increases up to 9 after contact communication with other PLs.
- PLs give and take knowledge with another PL at the same simulation step. (two way communication)
- PM does not exchange knowledge with PLs.

We execute the simulations with the following parameters set.

- "**# of PLs**": Number of PLs. This specifies the number of PLs in the project room which communicate each other. This number defines the scale of projects. If "# of PLs" is large, it means the project is large scale.
- "**Range of backdate**": Range of backdate to old e-mail-messages. This specifies the range of old e-mail-messages subjected for exchange knowledge between PLs by contact communication.
- "**Cycle of requests**": Cycle of sending e-mail requests from PM. A long cycle means a slow project operation. A short cycle means a short time delivery of a project.
- "**Steps stopping**": Number of steps stopping at the same place to communicate with another PL. This is modelled on the duration of a meeting. When this number is large, PLs can communicate long enough to exchange many kinds of knowledge. When this number is 1, PLs can stop only one step and exchange one kind of knowledge each other even they have many different kinds of knowledge.
- "**Random seed**": A random seed number which is used to initialize a random number generator of the simulation software. In order to avoid the impact of a random seed number, ten (1 to 10) seed numbers were employed for each simulation case.

How PLs Communicate Each Other

Figure 2 shows how two PL agents communicate each other. PLs are moving randomly in the project room. When a PL finds another PL is moved to neighbouring cell, they start communication.

In the Figure, A PL having knowledge 41736 gives some of the knowledge to neighbouring PL of 25381. After one step of communication, the PL of 25381 has knowledge combination 25481. Communication will proceed in such a way.

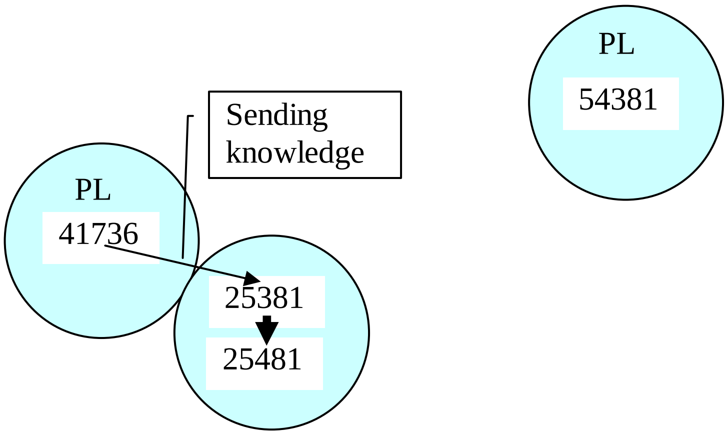

Figure 2. Communication between PLs

Flow chart of communication between two PLs

Figure 3 shows the main part of communication between two PLs. If no knowledge to exchange each other, they separate even the simulation step does not reach to the "Steps stopping". There is no possibility to be the best efficiency case in this simulation to stop in one place to keep communication with a certain PL for a long time, because the PLs have limited knowledge to exchange.

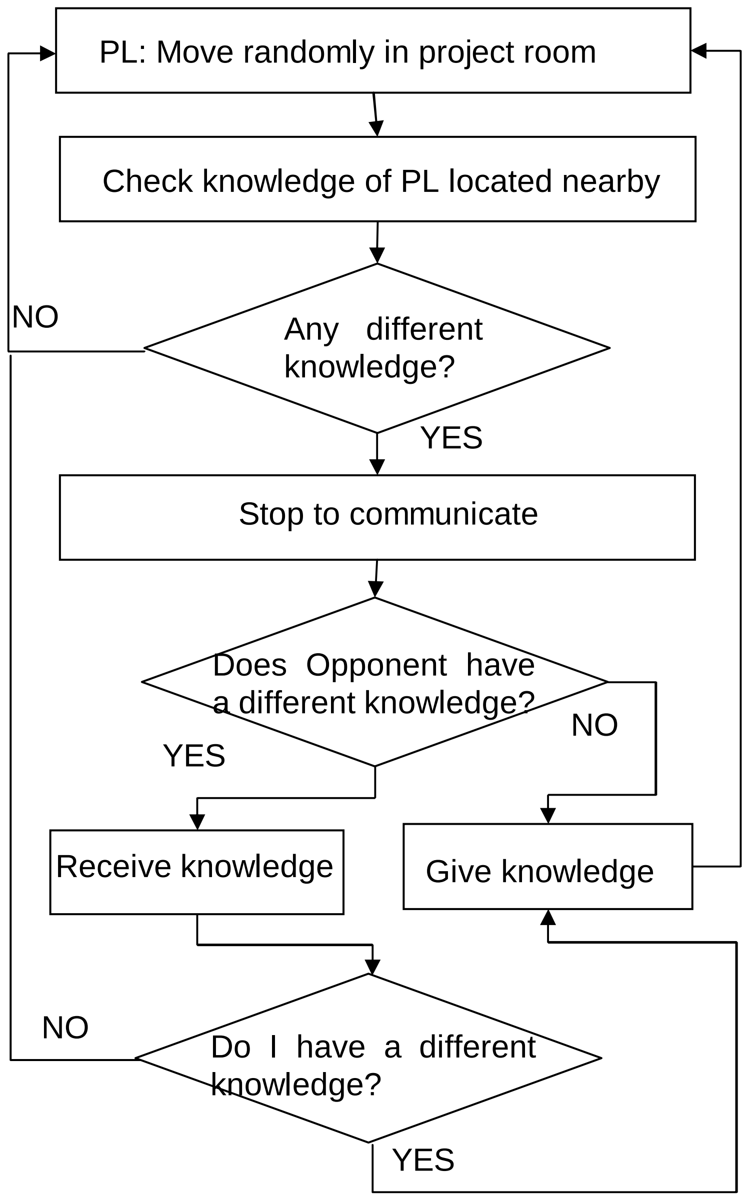

Figure 3. Flow chart of communication between PLs

EXPERIMENTS AND DISCUSSION

Experimental Set Ups of the Simulation

Simulations are made under the following set of parameters. The numbers of experiments are 250 times for the figures 4, 5 and 400 times for the figures 6, 7 and 8, respectively.

Table 1. Parameters for Figure 4 and 5

Name of parameters	Figure of parameters
# of PLs	4, 8, 12, 16, 20
Cycle of requests	1, 2, 3, 4, 5
Steps stopping	1
Random seed	1, 2, 3, 4, 5, 6, 7, 8, 9, 10

Table 2. Parameters for Figure 6 to 8

Name of parameters	Figure of parameters
# of PLs	4, 20
Range of backdate	1, 3, 5, 7, 9
Cycle of requests	1, 5
Steps stopping	1, 5
Random seed	1, 2, 3, 4, 5, 6, 7, 8, 9, 10

Definition of Efficiency of Communication

The word "Efficiency of communication" used in the figures is defined as:

$\eta = T / s / n$

Where η: Efficiency of communication, T: Total knowledge possessed by all PLs after simulation, s: Simulation steps, n: # of PL

The values of "Efficiency of communication" in the figures are the average of all parameter conditions other than the conditions in the transverse axle or the remarks of the figures.

Efficiency of Communication by "# of PLs"

In the figure 4, the larger the number of PL increases, the lower the efficiency of communication becomes. This means the larger the scale of a project becomes, the less efficient the communication becomes. Even if the project manager makes request by e-mail message to project leaders smoothly, the communication among the project leaders cannot achieve good progress in a large scale project. If this situation continues to the end of the project period, the total amount of knowledge shared among the project leaders are not enough to complete the project in good quality.

The approximate formula was calculated by regression analysis.

$\eta = 0.36 \times \mathrm{n}^{-0.49}$,

Where η : Efficiency of communication, n: # of PL

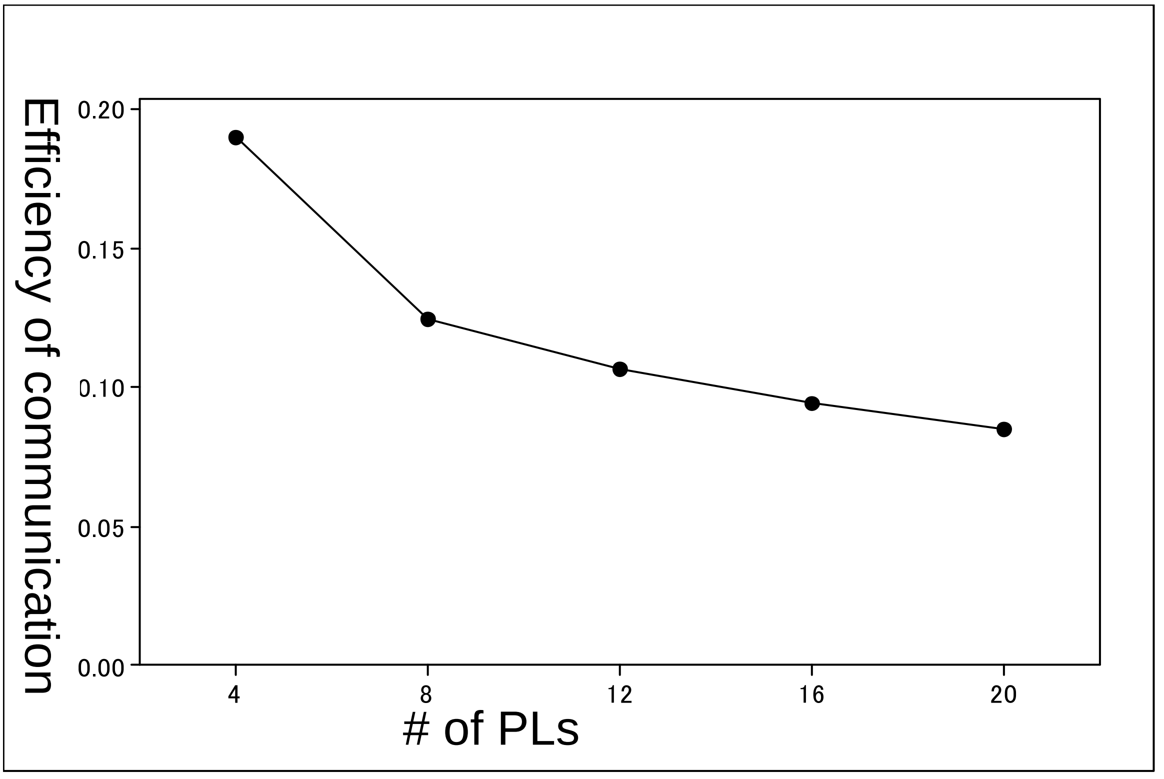

Figure 4. Efficiency of Communication by "# of PLs"

Relation between Efficiency of Communication and Productivity

We compare the formula obtained from this simulation with the ISBSG's formula.

The result of this simulation: $\eta = 0.36 \times \mathrm{n}^{-0.49}$

Where η : Efficiency of knowledge exchange n: # of PL

ISBSG's formula for productivity:

(Function Point/Person Hours) = $1/(C \times \mathrm{MaxTeam}^{E}) = 0.26 \times \mathrm{MaxTeam}^{-0.521}$

The productivity of projects is proportional with the efficiency of communication; because the indices in both formulae are close namely -0.49 and -0.521. This justifies our simulation shows actual communication in project.

Efficiency of Communication by "Cycle of requests"

In the figure 5, the longer the "cycle of request" increases, the lower the efficiency of communication becomes. In other words, if a project manager sends e-mail-request to PL in shorter cycle, the efficiency of communication becomes better.

The larger the number of PL increases, the smaller the sensitivity of the efficiency of communication by the "Cycle of requests" becomes. If a project manager sends e-mail-requests to PLs quickly and smoothly, this is not effective in a large scale project for improvement of communication efficiency.

Therefore, we found making a delivery period of large projects shorter is difficult comparing small projects.

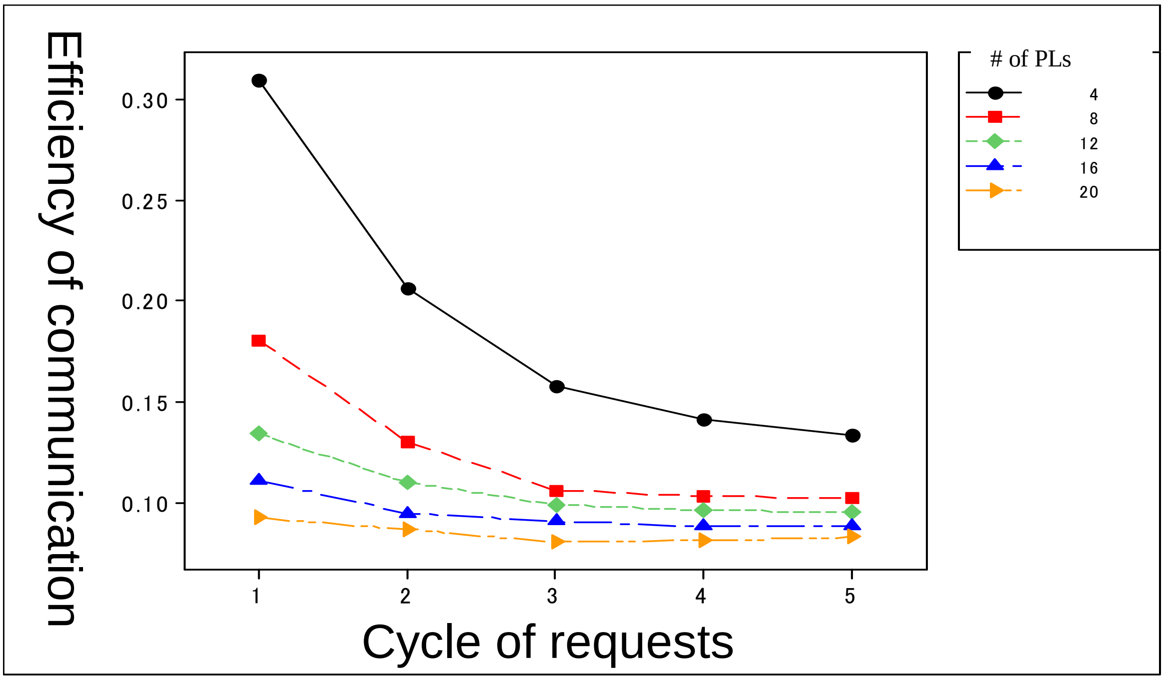

Figure 5. Efficiency of communication by "cycle of requests"

Efficiency of Communication by "Range of backdate"

In the Figure 6, the bigger the "Range of backdate" expands, the efficiency of communication is improved. This means that, in order to make the efficiency of communication better in a project, it is effective to communicate about many issues in one chance of communication. This effect is remarkable in case of big “# of PLs”, namely in a large scale project.

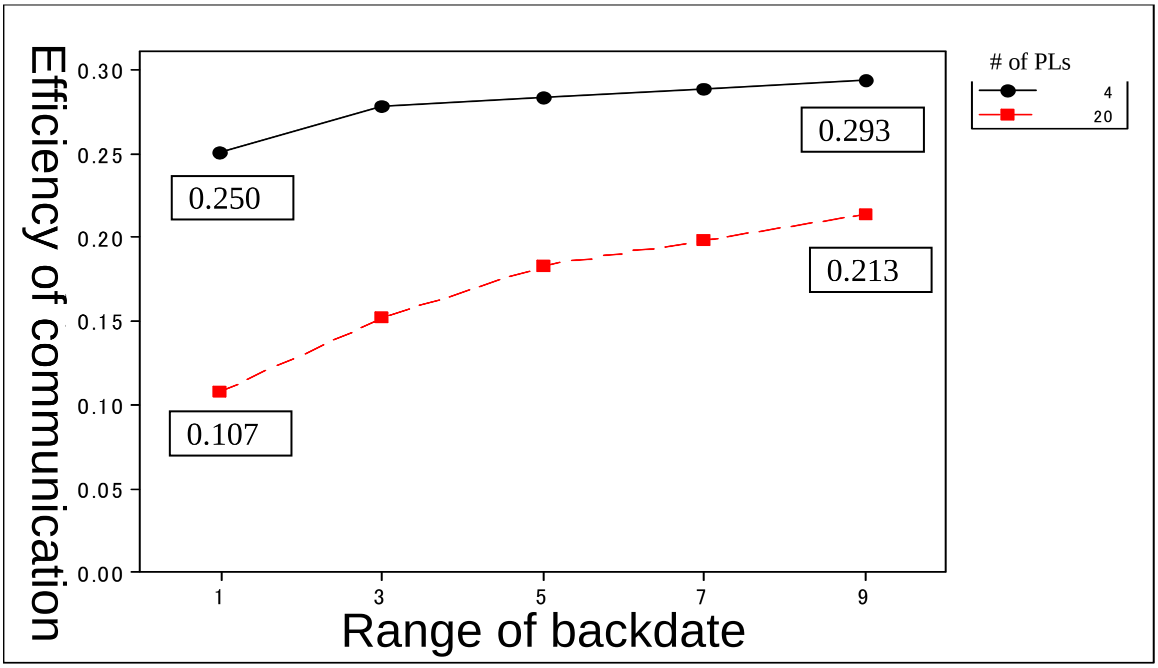

Figure 6. Efficiency of communication by “range of backdate” & “# of PLs”

We also knew, from the Figure 7, the efficiency of communication is not sensitive with “Range of backdate” in large “Cycle of requests”. This says if project manager does not send e-mail-request smoothly, the effort by PLs to communicate many issues in one chance of meeting is in vain. Efficiency of communication is depending on the effort of project manager.

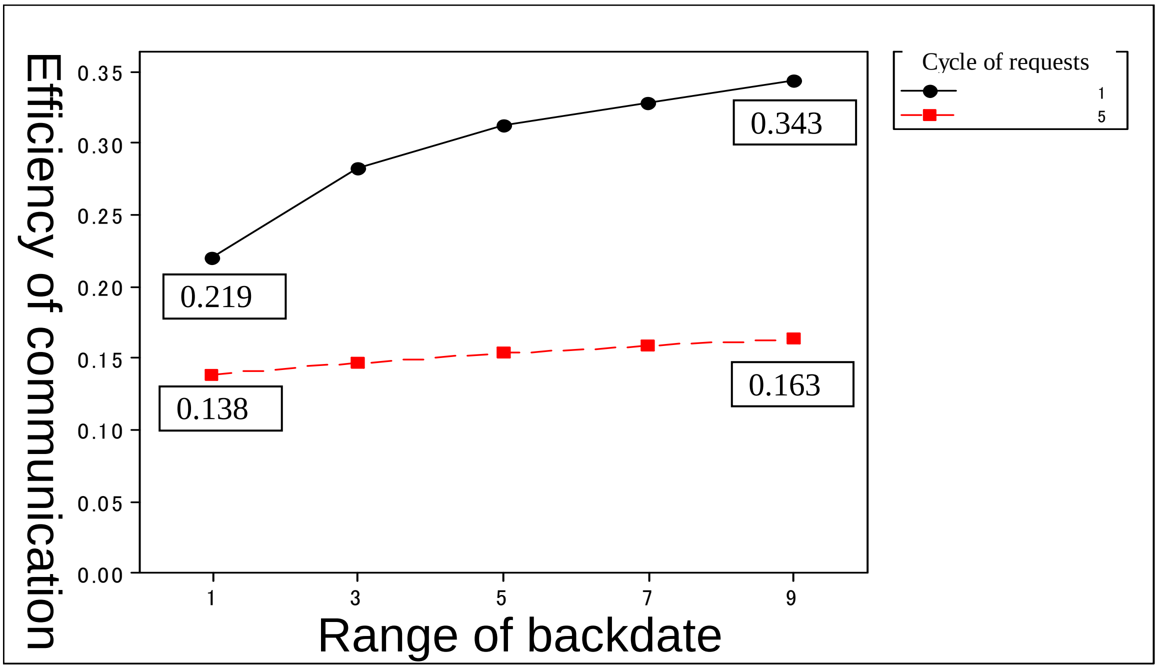

Figure 7. Efficiency of communication by "range of backdate" & "cycle of requests"

From the Figure 8, the effect of "Range of backdate" is large when the "steps stopping" is large. The efficiency of communication will be improved if a meeting is held in enough long time. In other words, using the same span of time, it is recommended to not split meetings to short but have a few long meetings and to communicate many issues in one chance of meeting.

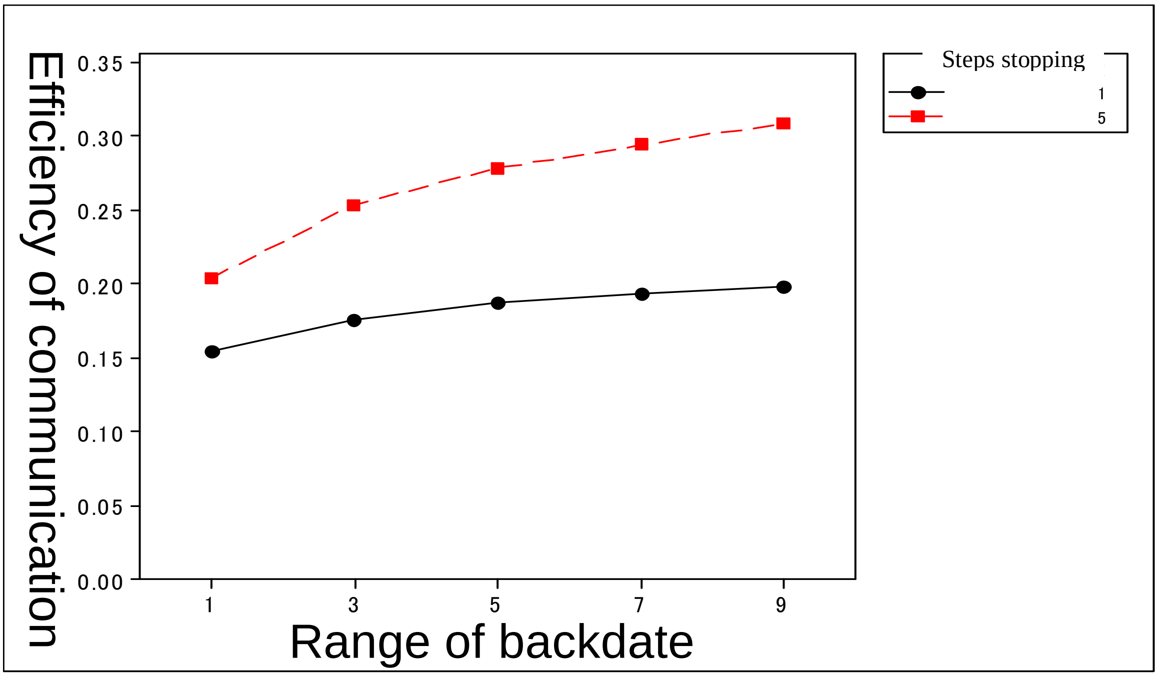

Figure 8. Efficiency of communication by “range of backdate” & “steps stopping”

In any size of projects, it is effective to take enough time for communication. Once PLs have a meeting in a project, they should exchange knowledge each other until the end of discussion for all issues they have. It is inefficient to separate a meeting to several meetings to finalize all issues.

CONCLUDING REMARKS

This paper investigates about communication processes of project members, which employs an agent-based simulation model to analyze the roles of mutual communications among members of a project team. The objective of the research is to uncover the characteristics communication efficiency in a large scale and short delivery project.

Major conclusions are: (1) the larger the scale of a project becomes, the less efficient the communication becomes. We have confirmed that making a delivery period of large projects shorter is difficult comparing small projects. It is caused by complexity of communication in large scale projects. (2) We have validated if project manage has to shorten the delivery period of large scale projects, it is not recommended to have many split meetings. It is recommended to communicate about many issues in a few numbers of meetings and take enough time for each meeting using the same time.

Our future work includes 1) studying to find better organization of a large scale of project team which is ordinarily organized as PM-PL-member, for example, about the best ratio of PM : PL : member, 2) study about the impact by pause of communication between PM and PLs since PM has too much work to do like trouble shooting.

ACKNOWLEDGEMENTS

We are grateful for the cooperation of Kozo Keikaku Engineering Inc., who provides us with Agent-Based Simulator “artisoc”.

REFERENCES

ISBSG. (2007). *ISBSG Special Analysis Report “The impact of team size on productivity and output”.* International Software Benchmarking Standards Group

ISBSG. (2005). *Practical Project Estimation 2nd Edition.* International Software Benchmarking Standards Group

Joshua M. Epstein, Robert Axtell. (1996). *Growing Artificial Societies – Social Science from the Bottom Up.* The Brookings Institution Press

Frederick Philips Brooks Jr. . (1995). *The Mythical Man-Month: Essays on Software Engineering*. Addison-Wesley Publishing Company, Inc.

Project Management Institute Standards Committee. (1996). *A GUIDE TO THE Project Management Body of Knowledge*. Project Management Institute

Robert Axelrod. (1997). *The Complexity of Cooperation*. Princeton University Press

Susumu Yamakage. (2007). *Instructions for organizing artificial society – Introduction to Multi-Agent Simulation by artisoc*. Shoseki Kobo Hayayama

Susumu Yamakage’s office website: < http://citrus.c.u-tokyo.ac.jp/English/index.htm>