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複雑系モデルに基づくアカデミック・ソサエティの盛衰予測に関する研究

－マルチエージェントシミュレーションによる大学人事システム考－

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あらまし 筆者らは、アカデミックソサエティの健常性を阻害する、あるいは助長する環境素因を明らかにすべく、複雑系科学の手法を援用して、大学-学会モデルの構築を行っている。本報では、特に、大学における組織運営システムに注目した。大学が、研究に加え、教育を主務とするその他の社会的要請に応える上で、如何なる組織形態が効率的であるか、すなわち、所謂、小講座を解体した教官独立型か、それとも従来の講座システム的チーム形成型のいずれが効率的であるか否かを検討した結果につき報告する。

キーワード 複雑系，マルチエージェントシミュレーション，大学-学会モデル

A Study on Ups-and-Downs Prospect of an Academic Society Based on Complexity Model

- What is an appropriate personnel system in a Japanese University? The Multi Agent Type Simulation knows! -

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Abstract Authors have been interested in the ups-and-downs prospect of an academic society including both a University and Academy, and then endeavored to develop the *University-Academy Coupling Model* in last a couple of years. In this paper, focussing on how different efficiency observed in different types of organizing process or personnel system for research activity in Universities, a simulation model based on the Multi Agent Type Simulation and their numerical solutions were shown.

Key words Complexity, Multi Agent Type Simulation, *University-Academy Coupling Model*

1. Introduction

1.1 General background for this research series

No doubt about a thing that the present prosperity of Japan has been drawn from its economic strength. And Japanese economy does not rely on her own natural resources but the system of processing trade and her power of industrial technology. However, recent depression is going to cover the whole nation in a very pessimistic atmosphere. In fact, several well-known intellectuals, some of them are Western scholars like Huntington [1], insist with likely prospect that Japan will lose strenuous power and has to face some sort of decaying on its society in near future. As one of the plausible causes for this, they predict that Japan will lose her scientific and technological priority to other nations, particularly in the field of advanced and hot areas such as bioengineering, generic science and so forth.

If so, the academic society composed or led by Universities and Academies is very responsible to avoid or overcome this pessimistic prospect.

Let me pick up a certain example. Fig.1 shows the flourish of *Architectural Institute of Japan, AIJ* that authors belong to as a main activity stage. In postwar Japan rapid growth of the economy required constructing demand that called for more building engineers, which obviously connected with increase of faculties at Universities or Universities itself. This is why the membership of AIJ has gone up almost constantly.

One curious thing is that the number of professors is seemed to keep its previous tendency after 1990s amid the depression, when constructing demand has become less and less. And addition to that, marvelous increase of published papers in the Transactions of AIJ during 1990s is completely coherent to the number of professors. This leads to a certain possible conjecture that the number of professors has swelled without any social or industrial demand insisting "Growing number of papers implies so much research demand that more professors is requisite." In fact, we are reluctant but have to admit that the quality of papers published in Trans. AIJ has been obviously degrading in theses days.

If this hypothesis is a reality of AIJ, or not only AIJ but also other matured academic fields, the situation of Japanese academic society that should support the power

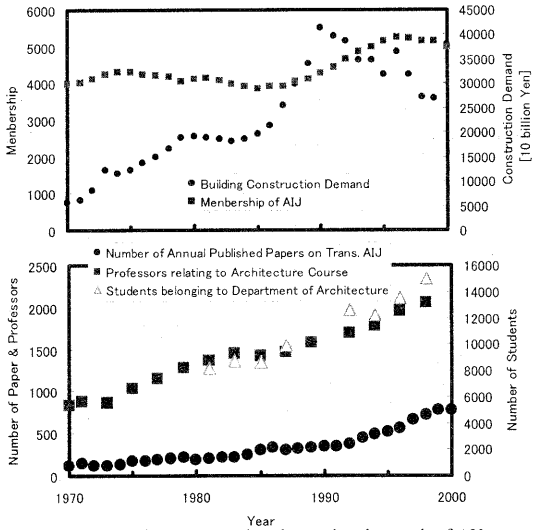


Fig.1 Time varying construction demand and growth of AIJ

of her industry stands a verge of dangerous abyss. We call this as the *Academic Decadence*.

The ultimate aim of this research series is to make some significant proposals to break the *Academic Decadence* (AD) so as to keep Japanese prosperity. For the time being, we have determined a primary purpose as to establish the *University-Academy Coupling Model* for the Multi Agent Type Simulation in order to make clear what evil environmental factors are significant on the AD or how to avoid this for our better future.

Some of our outcomes have been published [2], where the relation between several environmental factors and the AD was concerned. For instance,

- The robust and healthy reviewing system is very important to avoid the AD.
- The system for professors' alternation of generations is also key factor. If you estimate him only for his number of papers produced as his fruits, the society would go down to the AD. You have to take esteem on not only quantity but also quality of paper or research.

1.2 Target of this specific paper

In Japanese Universities, especially in national Universities, research activities are conducted within some sort of group, called as *Koza* that means a lecturing unit. This *Koza* consists of a professor and/or an associate/assistant professor and several research associates, which can be liken to a pyramid personnel system. This is very traditional system in

the history of Japanese University. Recent trend in the provision to reform Universities indicates that every faculty should be independent in every facet from research activity to grant earning, lecture responsibility or other duties. Because the traditional *Koza* system is regarded so stiff, where personnel flexibility is strictly limited keeping in static state. It's true that *Koza* should be discarded as evil system in a sense. However, it seems to be an extreme idea that any cooperative groups are prohibited and every faculty member *must* be independent never sharing requisite duties such as research, grant earning, lecture and else.

So then, at this moment, a simple and fundamental question is, perhaps, coming up.

In this pepper, we are going to discuss about a specific issue what kind of personnel system is appropriate to maximize research efficiency in Japanese Universities. The approach for this is regarded as one of the sub-models consisting of the *University-Academy Coupling Model.*

2. Model Frame

The model for the Multi Agent Type Simulation[*1] was developed, which intends to be a plausible figure for University World.

Although the ultimate target faces to social and particular Japanese concern, previously explained, the model itself sheds some light on a universal facet derived from the Artificial Intelligence. In other words, we are always so conscious of the model's expansion and generality not to limit on the very particular and narrow thing. Hence, first of all, we observed the real University World to extract several substances lying behind such as Agent's Competition, Cooperation, Organizing Process and so forth. And then, we intend to build them on the model never to lose the generality.

2.1 Artificial Society

The Artificial Society consists of two fields. One is defined as "Research Source Field" (RSF) where an Agent can earn seeds of research by digging those.

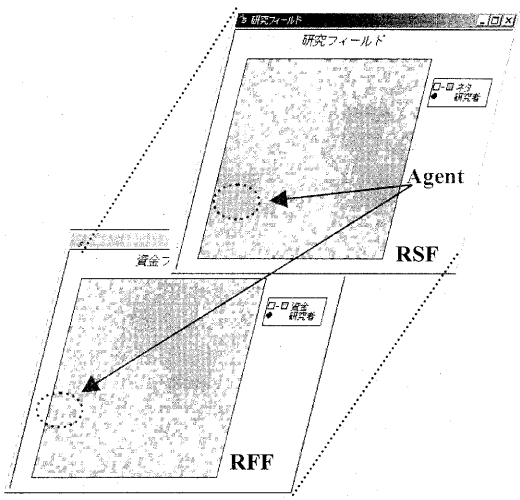


Fig.2 RSF and RFF, two fields consisting of the Artificial Society

Another is "Research Fund Field" (RFF) where he gets grant that is requisite to continue his research activity. These two fields have same x-y coordinate system as shown in Fig.2.

2.2 Agent

There are three types of Agent. First one is "Lone Wolf" who is entirely independent from any Research Groups. Second is "Research Associate", and third is "Professor". A Professor leads a Research Group to which several Research Associates belong.

Every Agent has several personal characteristic values such as age, Moving and Digging Abilities for both RSF and RFF respectively. Moving Abilities on both RSF and RFF are defined as constant amid his entire life, whereas Digging Abilities are variable. If an Agent has become a Professor, he adds his Digging Ability for RSF to one for RFF and regards it as his new Digging Ability for RFF. Also, if an Agent has become a Research Associate, he refines his Digging Ability for RSF by adding one for RFF to original one. One important thing is that a summation of Digging Ability for both RSF and RFF keeps constant through his life.

Every characteristic value relevant to Agent's ability and others is determined randomly when he comes to existence in this Artificial Society.

Complied stock earned at RSF expresses the Agent's Research Achievement (RA). Also, a stock got at RFF is defined as his Acquired Grant (AG). Both balances of RA and AG are very important for Agent's existence.

[*1] ***MAS*** was applied, which was developed by KOZO KEIKAKU Engineering Inc. http://www2.kke.co.jp/

Agents move on RSF and RFF to seek RA and AG. This moving may be likened to a professor's behavior to changes his research filed intermittently, or positive activity to obtain more research grant. Moving on two fields levies the Agent some costs on his RA or AG balances. The Agent is requested to endure some AG consumption to earn RA, vis-a-vis, he has to pay some RA to obtain AG. This may be understood that research activity inevitably accompanies some monetary consumption.

Every Agent who is over 60 years old retires.

Initially, every Agent starts as a Lone Wolf. After 2 years for his trial term, he can become a Research Associate or Professor due to latter explained rule, or of course, keep as a Lone Wolf.

2.3 Criteria Agent required

Every Agent is required to satisfy a certain condition to sustain his life as a researcher expressed as,

$$RA > C_{RA} \text{ and } AG > C_{AG} \qquad (1)$$

where C_{RA} and C_{AG} are criteria for Research Achievement and Acquired Grant, respectively. Someone who violates the criteria is purged immediately.

2.4 Alternation of generation

When a retirement or purge takes place, a new Lone Wolf Agent participates to this Artificial Society, whose characteristic values are determined based on completely same procedure as formerly explained. If the disappearing Agent is a Professor, his successor is selected within the Research Group immediately. One of the Research Associates having the largest RA is always appointed as the successor.

2.5 Intelligence of Agent and his Learning Process

Every Agent behaves in accordance with his own Will. The Will consists of 4 elements such as,

Str.1 Probability to seek a location on RSF within his own Moving Ability to maximize obtaining RA. Therefor, the value (1-Str.1) means a probability to seek a point on RFF to maximize GA. Str.1 makes sense only when he is a Lone Wolf or a Professor.

Str.2 Intensity of his will to apply for a Research Associate's position through open competition. This makes sense only when he is a Lone Wolf.

Str.3 Intensity of his will to express frustration as a Research Associate. This is effective only when he is a Research Associate.

Str.4 Intensity of will to accept his Research Associates' frustration. This is effective only when he is a Professor.

These are all defined as $0 \leq$ **Str.*n*** ≤ 1.

Every Agent modulates **Str.*n*** to maximize a 1st differential coefficient of newly obtaining RA that is understood as the Objective Function. This modulation process takes place every 3 month. So then, **Str.*n*** varies step by step in his lifetime. That's why this procedure is regarded as Agent's Learning Process. From the technical viewpoint, this should be called as the Optimization Process of which Objective Function is varying in its time series affected by dynamic environment. Practical solution for **Str.*n*** was adopted the Gradual Simplex Method [3].

2.6 Moving logic on both fields

An Agent moves on RSF and RFF at the same time. Both Lone Wolf and Professor Agent determine how to move by a value of **Str.1**. A Research Associate always follows after his Professor. In short, a Professor is very responsible what direction his Research Group is going to, which inevitably influences on their destinies.

2.7 Cooperative relation between Professor and Research Associate

A Lone Wolf Agent has to obtain both RA and GA by his own hands. To the contrary, if he join a Research Group as a Research Associate, he can specialize in research activity. Or he presides his own Research Group, he can specialize in earning research grant. Within a Research Group there is a specific relation between a Professor and Research Associates to maintain their own RA and GA balances in good shapes. This relation is kept by individual interest as latterly explained. A Professor expropriates a certain proportion of newly obtained Research Associates' RA. This proportion, called as Plunder Rate, is defied in every bilateral relation between a Professor and a Research Associate. On the other hands, a Professor has to distribute a certain proportion of newly obtained research grant according to bilaterally determined Dividend Rate.

2.8 Rules to generate/ demolish a Research Group

A Research Group is emerged by a specific rule as followings,

- Either Lone Wolf or Professor who has relatively

smaller RA than GA calls for a Research Associate.

- Other Lone Wolves who are lack of GA as compared with RA have primary intentions to apply for the position. Among them those Agents who have larger **Str.2** than a random number ranging [0,1] will really apply.
- If there are several expectants, the Lone Wolf or Professor chooses a guy who has the keenest research ability.
- The contract is confirmed where both the initial Plunder Rate and Dividend Rate are determined by Professor's asking price.

2.9 Spring Labor Offensive "Syun-tou" and corruption of Research Group

Every December, every Research Associate estimates the relation to his Professor looking back past 12 months whether it seems to be appropriate. If he has got more GA from the boss than expropriated RA by the boss, nothing happens. If not, he feels frustration. When the Research Associate feels the dissatisfaction and has larger **Str.3** than a random number ranging [0,1] at the same time, a negotiation against the Professor takes place. In the labor negotiation, the Research Associate asks lower Plunder Rate or higher Dividend Rate. In the reality, a certain compromise point is searched, which is determined by the previous Plunder Rate/ Dividend Rate, Research Associate's **Str.3** and Professor's **Str.4**.

If there is no room to compromise, in short the previous Plunder Rate is 0 and Dividend Rate equals 1, the Research Associate leave away from the group to become a Lone Wolf again. If the Professor has no Research Associates any more, he also becomes a Lone Wolf.

2.10 As an optional strategy that a Professor can take

In ordinal context, if a Research Associate goes out from a Research Group is completely dependent on his will. Additionally, we can suppose another possibility.

In short, as an optional strategy, a Professor can discharge one of his Research Associates.

If a Professor recognizes being under an unhappy situation, where his time-integrated expropriated RA is less than his total distributed GA, he immediately dismisses a Research Associates who is estimated as the most inefficient guy.

3. Simulation

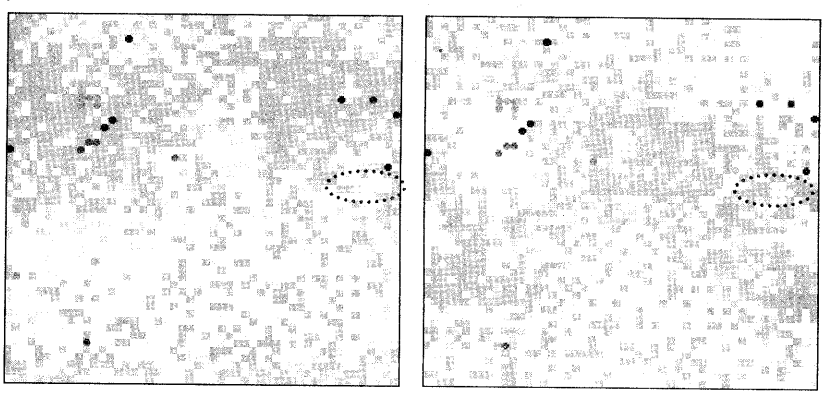
In the simulation study, a single simulation runs during 900 steps that is equivalent to 75 years in this Artificial World. Initially, 50 Lone Wolves are released into the fields. Fig.3 shows a screen in a simulation just passing 792 steps (66 years after the initial). On RSF you can see several blank areas. In those areas few research seeds is left. There are several Research Groups. A dot circle marks one of those.

4. Numerical Experiment

Focussing on several interesting points, a numerical experiment is conducted. Table 1 indicates assumed experimental conditions. Each case has 10 times simulation running to observe the Ensemble Average.

Table 1 Assumed experimental condition

	Case 1	Case 2	Case 3	Case 4
Can Agent make a group?	Yes	No	Yes	Yes
Criteria for existence C_{RA} C_{AG}	0	0	-500	0
Can Professor discharge his follower?	No	No	No	Yes



RFF **RSF**

Fig.3 A screen copy when a simulation is passing 792 steps (66years) from the initial.

5. Results

5.1 Personal Episodes

Let's observe several interesting individual episodes to confirm plausibility of the model. All these examples are picked up from Case 1.

Fig.4 shows an example entitled as "Research Associate of passage". He spends most of his carrier as a Research Associate once changing boss to serve. In the beginning of the relation with Professor #1, both Dividend and Plunder Rate are disfavor for him. However, he goes to get benefit those through Syun-tou, which remain stable during Professor #1. The fact being lower GA during his 50s implies that Dividend GA from Professor #1 is almost consumed to keep his voracious research activity.

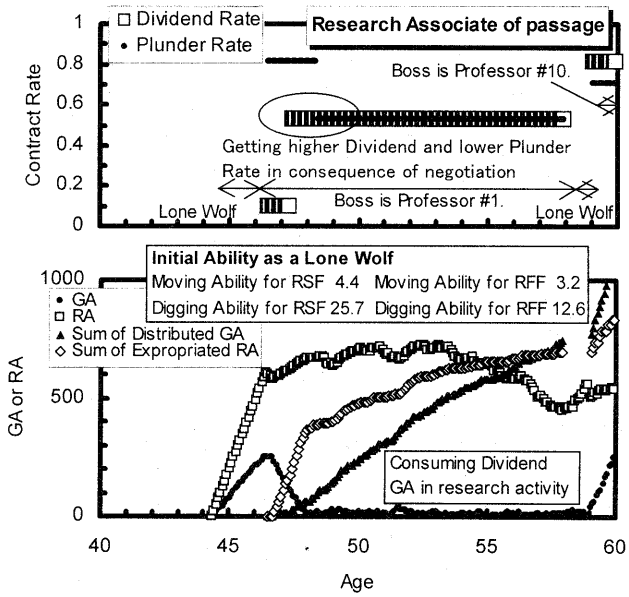


Fig.4 Personal Episode for a Research Associate of passage

Fig.5 is an example of a Professor having the brass to expropriate much form his Research Associates. One of the pregnant things is that he, probably, had learned "The best strategy for efficient plunder is to keep in relatively higher Str.1 and Str.4." Being higher Str.1 of the Professor possibly gives the Research Associates lots opportunities to get great RA. In that situation, the Professor can keep his steady RA income from his guys, even though he admits generous relations represented by low Plunder Rate or high Dividend Rate. To the contrary, if he responses relentlessly to his Research Associates, some of them may run away. This is not a good scenario for the Professor.

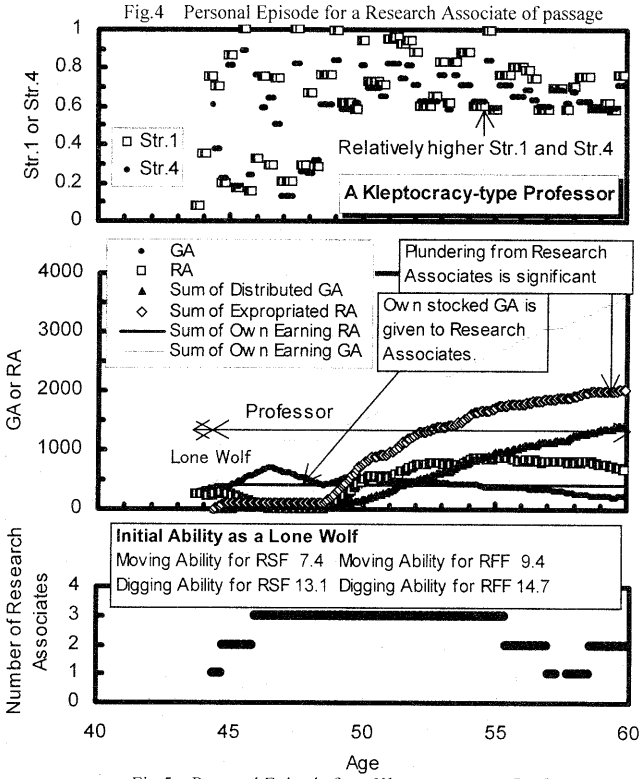


Fig.5 Personal Episode for a Kleptocracy-type Professor

Fig.6 is an example of a moderate Professor who is well managing to keep his group by balancing between sum of distributed GA to his Research Associates and expropriated RA from them. Observing the time series of both Str.1 and Str.4 after his 30s, you can notice an obvious tendency, where a period of higher Str.1 and Str.4 always appears after a period of lower Str.1 and Str.4 in turn. Amid the period of higher Str.1 and Str.4, the Professor lets his Research Associate focus on research activities and also takes generous attitude to them. On the other hands, during the term of lower Str.1 and Str.4, the Professor primarily intends to obtain research grant by his own hands and represses his Research Group at the same time.

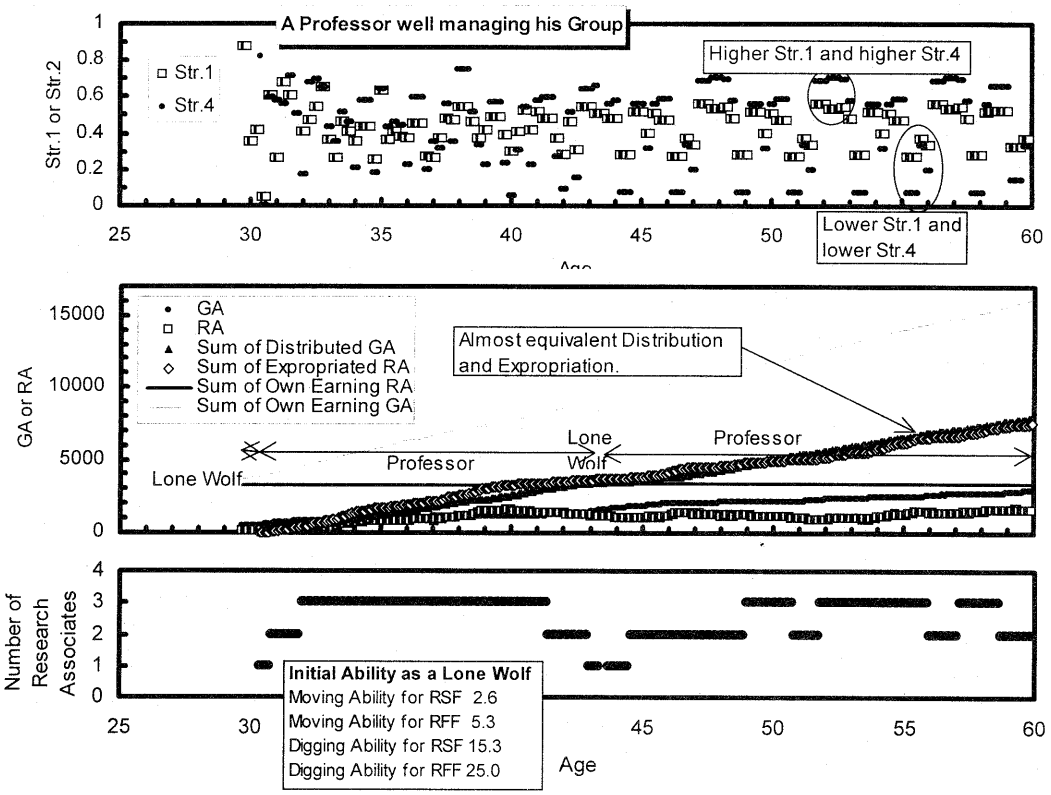


Fig.6 Personal Episode for a Professor well managing his Research Group

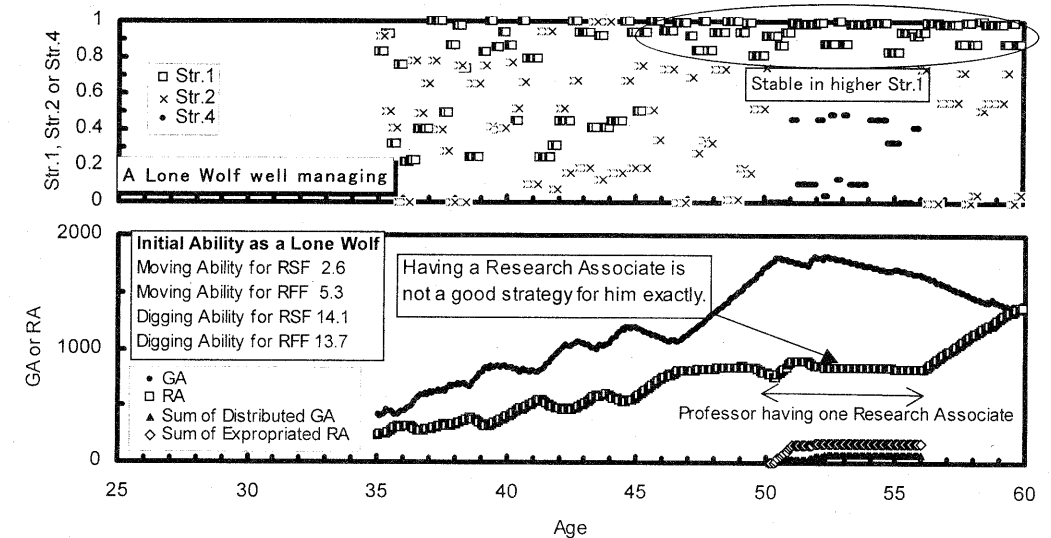


Fig.7 Personal Episode for a Lone Wolf well managing

Fig.7 shows an example of an Agent who is relatively successful as a Lone Wolf. During 50 to 56 years old, he employs a Research Associate. However, this doesn't seem to be a good strategy because of a week bond, where he gets less expropriated RA. So then, after retirement of the Research Associate, he never becomes a Professor but backs to a Lone Wolf.

All these discussion is surely only about a certain personal episode. However, we can confirm that they do behave based on their own rational judgements.

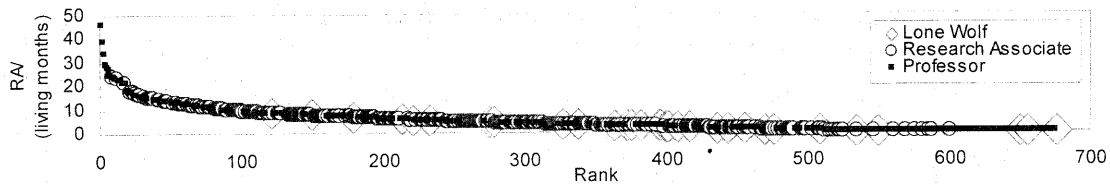


Fig.8 Rank of RA per living months for every Agent who could survive up to his retirement

5.2 Overview for Case 1

Fig.8 indicates a rank of RA per living months for every Agent who could manage to keep his live escaping the rule of Purge till the retirement. You may be little bite amazing there are only 676 Agents in 10 simulation running. Surviving only few Lone Wolves implies that this Artificial Society is not suitable for them. Whereas the fact that top 20 without 3 are all Professors may lead a simple principle, "You are required to become a Professor if you have an intention getting superior research achievement in this world."

5.3 Result of the Numerical Experiment

The result is summarized in Table 2. Every figure attached a particle "Sum" means that it's an average of 10 solutions on accumulative values observed at 900 step. Other numerical numbers means that it's an average of 10 solutions on time averaged values during 240 to 900 steps. A character "±" indicates a standard deviation.

Table 2 Result of the Numerical Experiment

	Case1	Case2	Case3	Case4
GA remains on RFF	74.5±1.34	61.7±1.10	85.3±1.33	70.6±1.87
RA remains on RSF	70.0±2.37	62.3±0.81	85.1±1.37	69.9±171
Averaged GA of Lone Wolf	182±85.9	520±112.3	180±119.2	246±102.2
Averaged RA of Lone Wolf	104±47.4	517±103.0	-34±54.8	171±72.1
Averaged GA of Research Associate	758±499.8	—	248±224.8	205±208.1
Averaged RA of Research Associate	721±238.7	—	235±157.3	613±170.1
Averaged GA of Professor	1031±262.7	—	570±246.1	918±271.1
Averaged RA of Professor	642±406.1	—	154±188.4	379±307.3
Sum of retired Lone Wolf	2.8±1.03	56.2±5.81	28.5±5.50	9.8±3.68
Sum of retired Research Associate	34.5±4.84	—	29.7±7.72	25.9±4.79
Sum of retired Professor	32.7±4.11	—	31.2±4.66	16.6±3.20
Sum of purged Lone Wolf	350.5±47.27	660.6±70.66	44.2±10.71	446.0±22.32
Sum of purged Research Associate	64.6±12.60	—	49.1±9.47	40.1±14.31
Sum of purged Professor	36.2±7.02	—	27.9±6.49	73.9±10.28
Averaged number of Lone Wolf	18.2±4.28	50	23.8±4.28	25.0±4.60
Averaged number of Research Asociate	21.3±3.67	—	16.2±3.23	15.7±3.39
Averaged number of Professor	10.5±1.95	—	10.0±1.73	9.3±2.06
Discharged Research Associates by Professor (Averaged value)	—	—	—	0.61±0.78
Averaged age of Lone Wolf	39.0±1.76	43.1±1.16	44.3±1.88	40.4±1.66
Averaged age of Research Associate	46.1±1.80	—	46.5±2.04	45.9±2.01
Averaged age of Professor	49.0±2.25	—	49.2±2.31	46.5±2.49

Every numerical number listed in the column "RA remains on RSF" indicates the inefficiency of this World from the research point of view. Thus, the value of 100 minus this implies the research efficiency of each case.

As you can recognize a comparison between Case 1 and Case 3, lowering the Criteria to survive brings the Society inefficiency, which seems to be plausible.

In this Society, if you endure a huge number of purged research fellows, a strategy to organize a Research Group promptly seems to be not necessary in a sense. In general, however, you can't carry on purge after purge, unless you have a vast population to supply myriad research fellows. So then, the option that the Professor has a possible strategy to dismiss a jerk-off amid his employing Research Associates is very rational to keep this Artificial Society's efficiency and health.

6. Conclusions

We come to following conclusions in this report.

- A model to simulate several situations related to the efficiency of research activity in University was built, which would seem to be one of our developing *University-Academy Coupling Model.*
- The results of numerical experiment did imply some interesting facets and encourage significant discussion.

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