New Research and Development Management System for RoboCup
– Genetic Management System of Research and Development –

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***Index Terms*—Genetic, Management, Research, Development, RoboCup, Opensource, Bazar**

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I am an official of the Ministry of Economy, Trade and Industry dispatched to Information-technology Promotion Agency, Japan (IPA), and am therefore not a researcher. I am currently helping the RoboCup Japanese National Committee at the invitation of Mr. Hitoshi Matsubara, who is a junior at the laboratory and a professor at the Future University Hakodate.

For someone like myself who is used to the bureaucratic and less flexible work in a government office, the activities of an NPO seem refreshing. Because of my job, I was particularly impressed by the method for managing research and development used here.

In order to effectively manage R&D and achieve goals, the introduction of the principle of competition in RD is believed to be effective. However, it is notable that the principle of competition is introduced in RoboCup in a way that is completely different from the management method that has been used in traditional large-scale research and management projects such as national projects (I call it the " Plan-Oriented Management System of Research and Development ").

At the same time, when looking at the circumstances surrounding R&D in Japan, it is undeniable that there is a sense of stagnation, such as a relative downturn in Japan 's technology level compared with other countries. When some sort of paradigm shift was expected, RoboCup made an appearance as a new method for R&D management.

In this paper, I am going to introduce the method for managing R&D in RoboCup (I call it the " Genetic Management System of Research and Development "), in the hope that it will be of some help for those who are interested in increasing R&D efficiency.

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I. Characteristics of the RoboCup Method

The characteristics of RoboCup include the following:

(1) being a Landmark Project aiming at the realization of one dream,
(2) being an international collaborative project that has spread to dozens of countries,
(3) being a grass-roots project in which anybody can participate,
(4) adopting an open source model so that research results are publicized and people can use or modify them freely,
(5) a lightweight administrative structure utilizing the Internet, and
(6) a place for competition (games) where results are objectively evaluated. A brief explanation of these characteristics is provided below.

A. Landmark Project

A landmark project is one in which a lofty and clear-cut goal that seems to be a dream at the time is set, and many researchers engage in the project for a long period of time to attain the goal. The Apollo Program is the most famous example of such a project. The economic benefits realized by achieving the goal are not the direct aim of such projects.

The goal of RoboCup is to use a team of completely autonomous humanoids to beat a human team that has won the FIFA World Cup by 2050. Although the goal seems grand, the people involved believe that it is not impossible, when considering what humankind has accomplished, including the breaking of the sound barrier 44 years after the Wright brothers first flight in 1903, the landing of Apollo 11 on the moon another 22 years later, or the victory of a computer over the world chess champion 51 years after the invention of computers in 1946.

As for the dynamic bipedal walking technology, which is now attracting attention, it was first successfully developed in 1979 by Professor Isao Shimoyama of the University of Tokyo, and, after 21 years, this technology has reached a level where it can be commercialized, with the appearance of ASIMO by Honda Motor Co., Ltd. and Sony 's SDR-3X last year. Robots that are capable of running are also expected to appear in the near future.

B. International collaborative projects

As is the case for Federation Internationale de Football Association (FIFA; translated into English as " International Federation of Association Football "), the internal governing body for soccer, " The RoboCup Federation, " was established

in Switzerland, and a committee for each country has been established under the federation. Researchers from various fields are engaging in RoboCup research in line with the game rules provided by The RoboCup Federation.

The 5th International RoboCup Competition was held in Seattle, USA from August 2nd to 10th, 2001, and 105 teams from 20 countries participated. It is thought that there are approximately 3,000 researchers from about 35 countries participating in RoboCup, including the researchers who could not participate in this international competition. This lack of exactness with regard to details is also a characteristic of a grass-roots project, which I describe next.

C. Grass-roots projects

The term " grass-roots project " here refers to one in which many researchers have gathered voluntarily to work on R&D of their own accord, with no R&D plan controlling the entire project or administrators with authority over budget or personnel issues. This is the Bazaar model, which was presented by Eric Steven Raymond in his book " The Cathedral and the Bazaar. "A representative example of the Bazaar model is the Linux operating system.

In a grass-roots project, the project cannot be established in the first place if the set visions or goals are not attractive, and the participating researchers will start leaving if the visions and goals become obsolete over time. As a result, projects that have no technological significance are eliminated.

D. Open source model

Being open source is one of the requirements for the implementation of a grass-roots project.

Open source is a concept that has spread through the field of software development, and it is thought to have originated with the GNU Project launched in 1985 by Richard Matthew Stallman. To summarize the concept of open source software, it has so-called " open source code, " which is available to the general public and can be freely modified or redistributed by anyone. However, open source does not necessarily have to be free, and the use of open source by commercial enterprises is not excluded.

In the case of RoboCup, it cannot claim intellectual property rights such as patents to begin with, as it is still in the R&D stage; however, the teams that participate in the international competitions are required to open their source code in addition to publishing papers at the international academic meeting held alongside the competition, so that the research results for each year concerning RoboCup can be shared with researchers throughout the world. This system allows all researchers to engage in R&D during the following year on an equal footing.

E. Light-weight organization in the Internet era

Although there is no R&D plan that controls the entire project or administrators with authority over budget or personnel issues in a grass-roots project, a human network is necessary for carrying out frequent information exchanges and the minimum required level of decision-making.

When looking at the organizations to which RoboCup 's 3,000 members from 35 countries belong, the largest number of them belong to universities. They also come from public R&D institutes and the research institutes of private companies, including even those who are not directly engaged in R&D, such as business administrators, media representatives, and government and municipal officials.

In order to maintain such a human network, which is made up of such a wide range of different types of members, a large amount of work and costs would be required in a conventional organization. However, in RoboCup, such maintenance is easily carried out through volunteer activities of members without even there being posts full-time staff, through the utilization of the Internet, including mailing lists.

In addition, both The RoboCup Federation and The RoboCup Japanese National Committee promote the streamlining of audits and other procedures and the reduction of maintenance costs through their choosing to be a non-profit organization as their corporate status.

F. An arena for competition where results are objectively evaluated

RoboCup holds games of various levels throughout the world, with an annual international competition placed at the top. In Japan, aside from the annual official game Japan Open, practice meets including the spring and autumn camps are held as well. These games not only gather a large audience, but also function as places where the technologies are evaluated by participants.

Whenever there are places for competition where results are instantly and clearly shown and where winning such competitions has economic, social or political significance, technologies have made rapid advancement. As representative examples of such cases, you can imagine motor races for automobiles or wars for aircraft.

It is believed that the large amount of research resources that have been assigned input amid the enthusiasm of the competitions is not the only reason for such advancements. The comparison among the competitors also makes it easier to adjust the allocation of research resources among elemental technologies, in the case of advanced technologies (high technology at the stage of competing for top performance). In addition, in the case of frontier technologies (high technology for which methodologies have not yet been established), it is believed that technologies will follow evolutionary paths that are effective, although not the best, by undergoing a selection process amid various technological ideas, which can be likened to the competition for survival among living things.

Moreover, it is obvious that the honor obtained through victory in competitions will motivate researchers more than achieving prestige through gifts and contributions in the hacker culture, as praised by Eric Steven Raymond, who was previously mentioned.

II. Genetic Management System of Research and Development

A. Problems in the Plan-Oriented Management System of Research and Development

It is said that the Plan-Oriented Management System of Research and Development adopted in Japan for traditional large-scale R&D projects represented by national projects is defective in that it is heavy and rigid, to put it simply. Taking a national project as an example in order to introduce the principle of competition and carry out efficient R&D, strict management is performed starting from the planning stage up to post-completion follow-up, involving innumerable words such as " meeting, "" assessment, "" system, "" organization, " " planning, "" prior evaluations, "" public tender, "" screening, " " report, " " account audit, " " monitoring, " " results, " " efficiency, " " intermediate evaluation, " and " post-project evaluation. " It is a different world to RoboCup.

Meanwhile, in such projects it is difficult to consider the ideas of engineers of small and medium sized companies or young researchers who have not established themselves in the academic community. In addition, since it takes about two years from the making of a proposal to the start of R&D, opportunities may be missed given that, with regard to the advancement of technology, time passes like dog years. Moreover, the large amount of paperwork places a heavy burden on researchers, and causes a bloated management organization.

B. Limitations of the Linux model

Developed in 1991 by Linus Torvalds, Linux has attracted attention as an operating system competing with Microsoft ' s Windows. The advantage of the research and development management system for Linux is that it combines a grass-roots model with an open source model. This has made it possible to utilize the brains of researchers throughout the world via the Internet, whether such researchers are affiliated with universities or private companies, at no cost. As a result, Linux has been updated at incredible speed with new features added with each new release, while stability has improved rapidly. Considered to be a management method that is highly effective for reducing inflated R&D costs and increasing the speed of commercialization in many software development projects, the Linux model is gathering attention in the United States and elsewhere.

However, the Linux model is only applicable to the field of software development. The reason is that, in the field of hardware, it is impossible to simply add new functions that have been developed in different parts of the world using a grass-roots model, as in the case of software; there is a problem regarding the allocation of space, and the overall balance must be reviewed as well. In addition, it is also essential to test the performance of the actual product and to evaluate whether a particular improvement is worth adopting. Moreover, the more innovative the added feature, the more necessary it is to perform a fundamental review of the design.

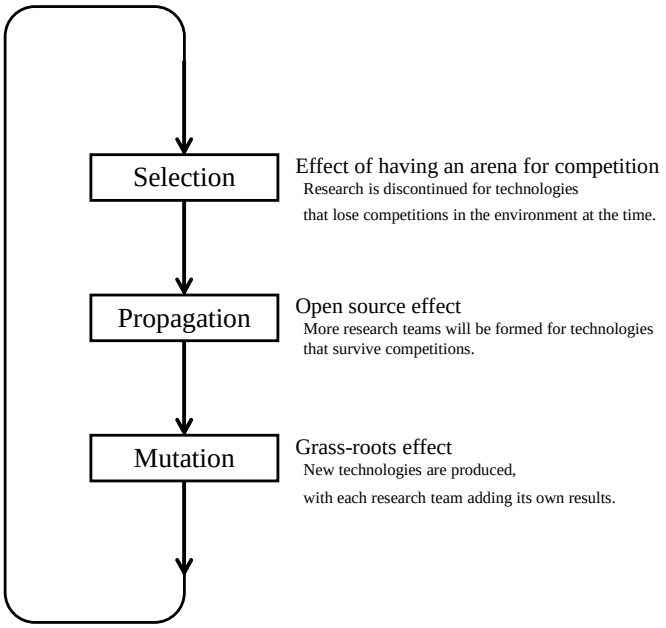

Fig. 1. Flowchart showing the Genetic Management System of Research and Development

C. What is the Genetic Management System of Research and Development?

RoboCup is epoch-making in that it has made it possible to apply a grass-roots model to R&D involving hardware as well, by introducing competitions where results are objectively evaluated. The essence of this RoboCup model is not a genetic algorithm but the Genetic Management System of Research and Development.

The Genetic Management System of Research and Development is a method of management in which the cycle described in Fig.1 is automatically repeated by an innumerable number of research teams toward an R&D goal, with the aim of efficiently attaining that R&D goal.

The evolution of genetic algorithms slows if the provided goal is too distant; therefore, a technique called the " moving target approach " is sometimes introduced, in which a tentative goal that is relatively close is provided and the goal is raised as the evolution progresses.

It is necessary to adopt a similar technique in the Genetic Management System of Research and Development as well. In the case of RoboCup, games are held under rules in line with the current technological level; for example, games are held inside a room with controlled lighting, with each team consisting of five wheel-type autonomous robots. In the future, the rules will gradually be made closer to the FIFA rules thanks to advancements in bipedal walking technology, image recognition technology and actuators, so that matches against human teams can become possible.

III. Effectiveness of the Genetic Management System of Research and Development

A. Speed of research and development

In the case of cutting-edge technology (highly advanced technologies for which methodologies have not yet been established), it is expected that the long-term goal can be attained more quickly with the Genetic Management System of Research and Development, compared to cases where the Plan-Oriented Management System of Research and Development is carried out. The reason for this is as follows: the plan that seems the best may not necessarily be the optimal path for reaching the ultimate goal. If the Genetic Management System of Research and Development is carried out, autonomous course correction will take place, resulting in the attainment of the goal more quickly. In addition, it should be kept in mind that making or changing plans also requires time in the case of the Plan-Oriented Management System of Research and Development.

Since RoboCup is the first case in which the Genetic Management System of Research and Development is being carried out, there are no case studies in which a goal has been achieved through the Genetic Management System of Research and Development. However, when observing the trends for results in each country, it is clear that, as the number of the participating country and teams increases, technology levels rapidly increase in the countries where there were not many results in intelligent robot research. Such countries include Singapore, Iran, Portugal, and China. This fact implies the effectiveness of the Genetic Management System of Research and Development.

B. Research and Development Costs

At present, it is not possible to compare the Plan-Oriented Management System of Research and Development with the Genetic Management System of Research and Development and judge which one is more cost effective. It is possible that the former system could create bigger savings in terms of R&D, as it can prevent overlapping research themes; on the other hand, it is also possible that the latter system could create bigger savings in terms of management expenses.

In the case of cutting-edge technology, it seems to come down to the philosophical issue of whether a creative achievement surpassing expectations (a breakthrough) will be produced by concentrated input of resources or by leaving the matter to the freewheeling thinking of individual researchers.

Here, it is also necessary to mention concerns it may not be able to recover R&D costs in an open source model.

At present, there is no need for concerns about the recovery of R&D costs in RoboCup, as each participating research institute procures R&D costs itself and volunteer staff support organization management. However, it is expected that in stages where the attainment of the goal comes in sight, private businesses will take the initiative in R&D instead of universities and the recovery of R&D costs will become an issue.

In fact, before Richard Matthew Stallman suggested the open source model in 1985, there was a case of an open source model being successfully adopted in a business scenario. This was the VHS project, which was led by Victor Company of Japan, Ltd. After the development of the VHS format in 1976, EP (Extended Play) Mode recording technology (1979) and High Fidelity Recording technology (1980) were developed quickly. It is said within the VHS camp that the adoption of an open-source model in which patents were offered inexpensively and new participants were widely accepted led to such developments, ultimately contributing to VHS 's victory over the Beta camp lead by Sony. Furthermore, the companies that developed these technologies were able to rapidly realize huge returns by licensing them thanks to the explosive expansion of the VHS market, while participants in the VHS camp were able to make major savings with regard to R&D costs.

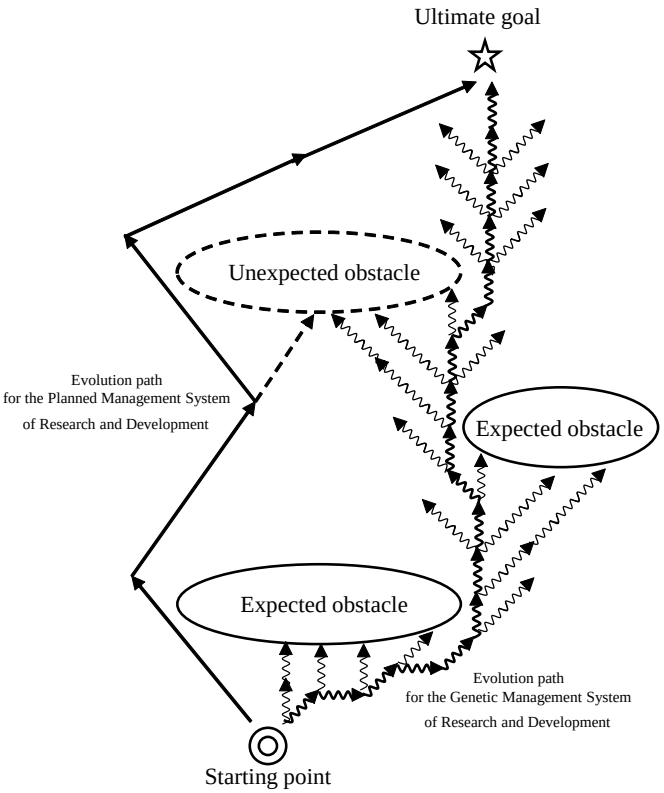

Fig. 2. Evolution path for research and development

Ever since then, there have always been cases where this open source model, in which intellectual properties are pooled and released for profit, has been adopted. A famous example is MPEG-LA (MPEG Licensing Administrator), which was formed in 1992 at the suggestion of Baryn Futa. MPEG-LA consists of leading world enterprises as well as Columbia University in the United States, which possess the essential patents for MPEG2, and is making great contributions to the popularization of DVD and other equipment. One reason that has been pointed out for the success of MPEG-LA is the existence of Columbia University as a neutral organization that can treat each company in the same way.

If this is applied to RoboCup, the NPO that currently manages the competitions through the formation of rules will

grow into an organization that co-manages the research results of RoboCup, based on the reputation and track record it has achieved. This NPO will examine the research results concerning RoboCup, select which companies or other organizations should possess important inventions or essential technologies, and shall conclude deposit agreements with such companies or organizations. Eventually, the package of intellectual properties related to essential technologies will be provided to all companies that require them at a low licensing fee. This will spare the licensing company the trouble of entering a contract with each developer, and the inexpensive license fee will allow such companies to enter the intelligent robot market more easily. On the other hand, rapid expansion of the intelligent robot market will allow developers to recover R&D costs even with the inexpensive licensing fee.

As was described, even if the Genetic Management System of Research and Development is adopted by a private company, it can be established as a business model during the take-off period of the market by involving a neutral organization that co-manages the intellectual properties. In addition, in the past decade, an increasing number of companies, mainly in the electrical machinery industry, have declared that they will license the patents they hold on a fee-based basis. The concept that market revitalization through increasing the number of participating companies is more beneficial for the developers than monopolizing the market by using intellectual properties is becoming more common; therefore, it seems that there is sufficient potential for the spread of the Genetic Management System of Research and Development.

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Osamu Naito completed the master’s program at the Graduate School of Information Engineering, University of Tokyo and joined the Ministry of International Trade and Industry in 1981. Currently he has been dispatched to IPA (Information-technology Promotion Agency, Japan) from 2001 (as Director of the IT Security Center), and is a part-time instructor at Tokaigakuen University Graduate School. He has been engaged exclusively in Small and Medium Enterprise Development Policies, including the formulation of the Temporary Law concerning Measures for the Promotion of Technological Development of Small and Medium Enterprises, which is the first law that promotes venture business, and the succeeding Temporary Law concerning Measures for the Promotion of the Creative Business Activities of Small and Medium Enterprises.