A Study of the Synchronization Process for Collaboration between Product Development and Fundamental R&D

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Abstract -We study a process that enables the accumulated results of proprietary basic research to be leveraged effectively in in-house development of that company's products, and propose a third synchronization process that links the two existing processes of basic research and product development. This synchronization process was devised based on modeling of undocumented discussions and decision flows observed on the frontlines of the two existing processes (basic research and product development), which are executed under different timelines. The authors also discuss a method for establishing this synchronization process in organizations and putting it into continuous practical use.

Keywords: basic research, product development, synchronization process, pilot team, scientific-level

1 INTRODUCTION

Manufacturers today have been exploring methods of new-product-planning using competitive in-house technologies. In the home appliance industry, for example, Japanese manufacturers founded after World War II established their position in the industry by using the strategy of emulating European and American companies in terms of their superior quality in manufacturing systems, while also applying the industriousness of Japanese workers.

After a while, the Japanese manufacturers began gradually shifting their mindset from *learning* to *creating*. This shift in strategy led Japanese manufacturers to focus on advanced research and development (R&D) activities, which resulted in a steady flow of attractive new products into the consumer market.

Economic prosperity led the Japanese economy to the stage of higher worker salaries. This reduced the cost-effectiveness of manufacturing somewhat, but Japanese companies continued their efforts by implementing cost-reduction strategies to balance out their competitiveness in the worldwide market.

At this point, the pace of development in the information technology field had been accelerating rapidly, and these changes led the manufacturers to start including business models in their product-dependent businesses. This changing situation led to great advances in the ways that products were developed. In particular, the importance of software has dramatically increased, and major functions that had once been based on hardware are now largely implemented with software.

Unfortunately, those changing trends led to a time of confusion for some companies. Moreover, some manufacturing companies turned their attention away from fundamental R&D to application research that contributes directly to commercialization.

Companies also began to promote various types of cost-reduction strategies; these strategies started in factories and were expanded to other departments such as the product development or administration departments. Under these circumstances, the model cycles have been gradually shortened, and this change led people to misunderstand the trend as evidence of improved R&D processes.

In fact, third-party technologies can be effective in developing new products. However, the trend of depending on a faster model cycle can lead to difficulties for companies that do not have a lot of experience with such cycles. Moreover, some of the resulting products lost their unique competitiveness. This situation narrowed the factors leading to success in the competitive environment down to lower production costs.

The objective of the authors is to take a second look at the role of fundamental R&D activities within manufacturing companies. To be more concrete, we should define and build a complementary process in which fundamental R&D is synchronized with product development.

However, there are great gaps between technologies and products. There are also some classic issues in technology management. One is known as the “Devil's River” [1]; this refers to the gap between the fundamental R&D and the product development processes. The “Valley of Death” [1] is another issue that lies between product development and commercialization. From the viewpoint of the marketing department, manufacturers must overcome the “chasm [2]” to reach their mainstream segment.

The authors set up a hypothesis that if we could build a mechanism to synchronize the two major processes of fundamental R&D and product development, the ideas that were generalized as a result could become the new basis of product development.

This paper discusses a new synchronization process based on the hypothesis; it discusses how to fill gaps between fundamental R&D and product development.

The rest of the paper is as follows. Chapter 2 describes existing product development processes. Chapter 3 extracts the success factors based on two case studies of mobile phone development. Finally, chapter 4 defines the proposed process and validates its consistency using the two case studies introduced earlier.

2 GAPS BETWEEN BASIC RESEARCH AND PRODUCT DEVELOPMENT

This chapter describes the current status of development models and the hidden problems.

2.1 Increased Complication in R&D Processes

Product development processes, especially for information communication technology (ICT) products, have become increasingly complex. In particular, the affordable development period for fundamental R&D has been becoming gradually shorter [3]. In contrast to the early days of this industry, it would be too late for a company to start and complete the R&D process in the required period if this process was started upon receiving a request for a product from a business unit.

Takeuchi and Nonaka [4] observed several Japanese manufacturing companies and found that they had been changing their product development style from “sequential” to “overlapping.”

In practical situations and in standard specifications, manufacturers use a certain number of third-party components at affordable prices. However, it would be harder for manufacturers to develop a unique competitiveness using only third-party technologies.

Furthermore, many changes in the development process may be necessary, depending on the strategies used by competitors. Such changes may not only include an earlier completion deadline but also frequent specification changes. If the R&D teams are not able to keep up with the turbulent processes, they will lose a business opportunity in the next model cycle. More than ever before, the current R&D processes must be able to contend with such an uncertain situation.

2.2 Discussion on Time Scale

To highlight the current manufacturing situation, the authors observed the problems that exist in the actual management of technologies using classical process models. However, the observation results indicated that those reference models were not suitable for describing the authors’ intentions. The details are as follows.

The major innovation process models that describe the relationship between R&D and product development are the *linear model* and the *linkage model*. [5] The former is a classic R&D model, which represents processes to be connected to process components in series. The “linkage model” [6]-[8] was proposed in the 1990s to improve the deficiencies of the linear model by adding the actual process in manufacturing fields.

According to the authors’ observations, the core elements of the two models are based on a common concept; two of the major differences are the starting point of each process and the feedback of know-how flowing across the processes, even in the backward direction, to upstream processes such as the R&D process. However, in the practical planning and development phases, the primary requirement is to ensure sufficient time-to-market, which means the required time span to achieve commercialization. Thus, it is essential to observe the process in terms of management on a time scale. These existing models, however, lack the information flow or mechanism to converge the development processes into a concrete goal. Therefore, the authors carried out the study in order to prove the need for synchronization of timing to establish a concrete launch date.

In the early 1990s, when the two models previously mentioned were proposed, competition in the high-tech industry was not as fierce as it is today. In addition, widespread access to the Internet by consumers could be one factor that has exacerbated the competition.

Figure 1 illustrates the situation of the general relationship between fundamental R&D and product development.

In the consumer products category, the typical model cycle of Fujitsu’s mobile phones takes approximately six months to one year. On the contrary, a study reported that the average period of R&D for a typical product in the electronics sector in Japan is 17.8 years [9]. This means that the time spent on R&D processes could be a severe burden or even a fatal factor in the entire cycle of product development. In this situation, manufacturers would probably decide to reform their organizational structure and adopt an accelerated product cycle in order to maintain

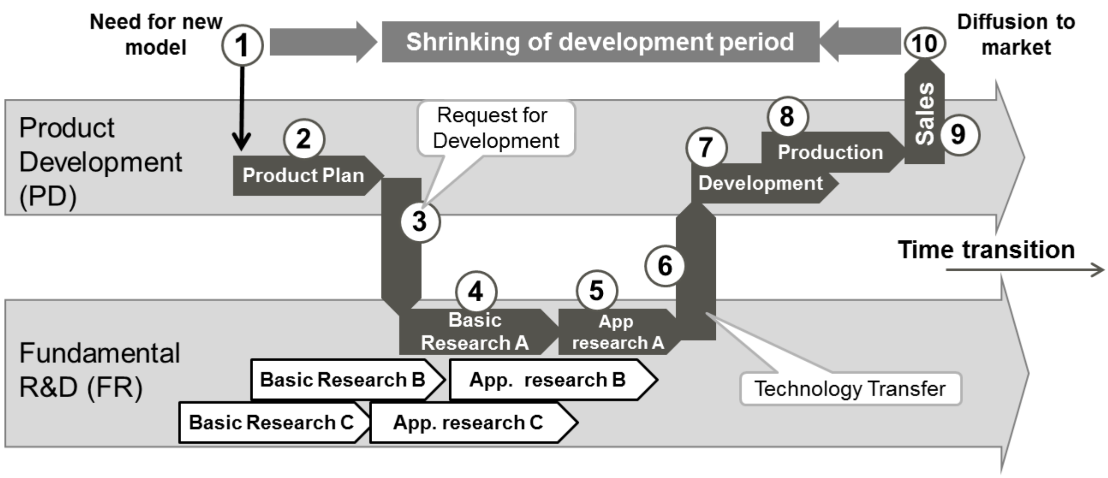

Figure 1: Fundamental R&D and processes of market-driven product development

competitiveness. The simplest solution would be to integrate the R&D department into the business unit. However, this kind of organizational reformation would lead to a decline in R&D activities, and finally, a collapse of the R&D process. Ultimately, the internal source of competitive technologies would be lost.

Another major discussion issue regarding the outcome of R&D is how to achieve product commercialization in the appropriate timing. This is described in related work in this area as *corporate technology stock (CTS) models* [10], [11]. Technology stock refers to all of the knowledge that exists in the R&D department such as technology documents, patents, and implicit knowledge. The value of technology stock is assumed to decrease with time. However, the authors surmise that the value of technologies accumulated through basic research could be maintained and increased by finding promising applications. The authors believe there is a mechanism to control the value on a time scale. In fact, discussions on time scales for manufacturing processes have recently been coming to light.

2.3 Issues in Current R&D: Discussions on Time Scale

In the product development process, items (4) and (5) in Fig. 1 should strongly focus on the fundamental R&D to maintain product competitiveness. However, the older-style organizational structures do not have the flexibility when it comes to the issue of how to provide the business units with expected technologies. A general approach to solving this problem involves two aspects, which must be well balanced. One is maintaining the independence of the R&D and business units; the other is determining the launch date and the expected quality of the product. The product development process should be carried out considering the issues listed below.

(1a) Business units should conduct a thorough investigation to screen technologies applicable to their products. This process should be conducted for both in-house and third-party technologies. An early start of the investigation would make it possible to obtain good results.

(1b) Promising technologies should be applied to multiple products with as few modifications or as little tuning as possible. Typical technologies are not fully ready to be adapted to new applications on demand. Therefore, organization-wide efforts to maintain the technologies are very important.

Measures for R&D departments are described below.

(2a) Product planning teams in business units expect the R&D teams to provide scientific knowledge. This should be done by not only following the classic *waterfall* style (Fig. 1), but also by exploring business opportunities where the technologies were not assumed in the planning stage. This sort of contingency to keep the possibilities open for different types of applications would increase the possibilities for discovering and applying innovations.

(2b) Applying rapid adaptation process to different fields
Typical research outcomes are tailored to particular applications that are described in the planning phase. Therefore, converting those outcomes so that they are adapted for different products requires a great effort to overcome the boundaries in technical and timing issues. Also, any issues concerning organizational structures and operation must be resolved in order to find new application areas where the technologies can be applied.

(3a) Issues in identifying applicable technologies
The R&D department should set up an information pool for “Research A, B, and C” (Fig. 1), in which the outcomes of R&D are stored and maintained.

Managing technical information using electronic media and autonomous management technologies will not cover the necessary functions to arrange matching of technology seeds and products beyond examples. Knowledge management of humans (research) is therefore essential.

(3b) Problems behind application of technologies
There are considerable obstacles in applying technologies in different areas. After the research process has reached the “Research (4)” or later phases in Fig. 1, conversion becomes different from earlier stages.

The authors have analyzed the above descriptions in order to outline the policy for considering new processes.

2.4 Applicable Strategies

The proposed strategies for product development departments are as follows.

(1a) Establish a protocol to discover promising technologies from a broad range of sources, and apply the technology to the product as a new application. To do this, processes to train engineers or researchers who can introduce new technologies and create a new value proposition for the products should be designed and implemented.

(1b) R&D teams should plan distinctive research themes based on expected emergent needs as quickly as possible. Precise market forecasting of mid- to long-term trends makes it possible to create practical research plans that may lead to marketing success. However, such decisions in practical management sometimes result in unintended strategies that reflect an estimated investment effect or an individual decision to set priorities among research themes.

In the fundamental R&D department, the following policies are applicable.

(2a) Adaptation process with the minimum impact:
In business units, the ideal goal of utilizing fundamental R&D is to reach the final stage of product development, where the technologies are completely adapted or tuned to the target products. From the perspective of R&D, a better strategy is to define an “intermediate stage” in the research

processes and accumulate the R&D results. This new mechanism will make it easy to meet the requirements for adaptation even if a research theme is underway and not complete.

Finally, there is one strategy that is independent of any existing organizations.

(3a) Capabilities to combine technologies with unknown applications

New ideas for products and businesses are not produced using only the above-mentioned mechanism. Every researcher and engineer should have the ability to manage uncertainties in the project and to explore new combinations of technology seeds and markets.

3 CASE STUDIES

This chapter introduces two examples of product development involving cell phones designed for senior customers.

3.1 Background

At Fujitsu, the development of cell phones specialized for senior citizens started around 1998. The marketing department raised questions about entering this kind of market, since there was no significant marketing information to support the plan. The core members of the planning team convinced the others that there would be substantial market expansion. At that time, however, the cell phone market for younger generations was growing rapidly. People opposed to the idea of only developing phones for younger generations insisted that they should plan products for senior users by composing a product "subset" with essential components taken from the mainstream line for younger customers with a minimum impact on the development cost.

The product-planning team conducted an in-depth study on the market segmentation. These detailed processes are described in [12]. As a result of their discussions, they selected three core concepts to focus on while developing a phone for senior users: ease of listening, ease of looking at (e.g., numbers and letters are easy to see), and security (for personal health and safety, or other factors). These core concepts have been selected for use over the long term in the new category of cell phones for senior users.

In reference to the above core concepts, the following sections trace the development history of two key technologies: motion-sensing and voice signal processing [13].

3.2 Case 1: Motion-sensing Technology

The motion-sensing technology used in mobile phone handsets is designed to help digitize information on a user's activities, for example, exercises, sporting activities such as golf or running, or information beneficial to personal healthcare applications [14]. The original concept of this technology was created for application to HOAP-1, Fujitsu's humanoid robot released in 2001 [15]. The unique algorithm that supervises the motion of the humanoid robot was composed of self-learning algorithms inspired from biological nervous systems that could be described using mathematical models. The following sections describe the development history of motion-sensing technology in three stages.

Stage 1: Unfound needs and seeds

The first generation of the *Raku-Raku* phone was equipped with a pedometer. However, the pedometer function was based on a third-party company's technology. In this situation, the R&D team did not have a chance to meet the needs of the business units since the researchers were concentrating on commercialization of the humanoid robot.

Stage 2: Commercialization of in-house pedometer

The R&D team created a prototype pedometer customized for mobile phones. The business unit evaluated the prototype and approved it for commercialization in 2006. The commercial success of Raku-Raku phone [16], [17] was achieved because the different workflows (of the R&D and business units) were organized to obtain the appropriate timing for the product release. The R&D team was seeking business opportunities other than in the robotics industry, and the business unit was focusing on a new strategy to expand the cell-phone market. The most significant step that resulted in the commercialization was an idea the R&D team had. They redefined the original role of the algorithms (for the sensing motion of robots) into "sensors that identify human behavior."

The main factor for the R&D team was accumulating knowledge of this technology at the *generalized* level, which means understanding the technology through the fundamental scientific basis that led to the technology. At the same time, the business unit was investigating in-house technologies that were applicable to a pedometer on a cell phone. However, the true intent of the business unit was to reduce costs by introducing in-house technologies. In the product development process in the business unit, the R&D team worked on their original process to tune the algorithm for the pedometer. The team completed the process within a month, an exceptionally short period, using their tuning technique. This achievement was outstanding in terms of the development of a new function, which often contains many uncertainties.

In stage 2, the following factors led to a successful development.

- A common goal of the two organizations emerged: commercialization of an in-house pedometer
- The R&D team cultivated an outstanding ability to apply a new technical challenge to new categories of products that they did not have experience in.
- The tuning technology accelerated the time-to-market and resulted in additional value for the business unit.

Stage 3: Expansion of product lineup

The broad utilities of the motion-sensing technology had come to the attention of the business unit during the process of developing the new cell phone. The R&D team started to upgrade the technology in their efforts to develop devices that could monitor human activity. The new activity monitor contained a gyroscope and an accelerometer, which enabled detection of human activity (e.g., walking, jumping) with the cell phone. The outcome of the development was demonstrated in a prototype cell phone displayed at a tradeshow in around 2008. In this demo, the prototype synchronized the motion of animation with a character in the virtual space of an application.

Next, the business unit initiated the development of new and high-value-added applications utilizing this technology in a shorter period than expected. These applications were based on the original tuning feature, which enables algorithm programmers to develop algorithms for new applications without requiring specialized technical or scientific knowledge. The motion-sensing technology was adaptable to particular sports that have a certain pattern of motions such as golf, walking, and running.

In stage 3, the following factors contributed to success.

- The supplemental technologies helped in customizing the advanced motion-sensing algorithm.
- The principle of the technology as described in advanced and complicated mathematical expressions was understood and shared with other team members by a key person in the business unit. This in-depth sharing of information accelerated the commercialization of the pedometer.

The achievement of this technology was the creation of the new function category of *motion sensing* in cell phones.

In 2012, Fujitsu released a new pedometer for dogs, which was achieved with the motion-sensing technology [18]. The applicable industries for this technology have been increasing.

3.3 Case 2: Voice-processing Technologies

This section describes the voice-emphasis technologies that are essential for increasing the clarity of the voice in conversations conducted on cell phones.

Stage 1: Start of development in a virtual organization

Fujitsu Laboratories has been developing voice/audio processing technologies since the 1980s.

The mobile phone business unit decided to plan a new model cell phone with competitive voice-emphasis features. The decision was prompted by the fact that the business unit was able to grasp the progress of R&D themes in Fujitsu Laboratories in terms of completion rate and expected commercialization timing. That information-sharing simplified the decision. The business unit had been organized under policies that encouraged the use of in-house technologies in their products. Those policies had continued in subsequent generations of mobile phones. That atmosphere fostered a strong relationship between the R&D department and the business unit.

The development team was organized into a cross-functional *pilot team*, which consisted of members from both the R&D team and the business unit. The pilot team discussed voice quality on cell phones based on concrete data of the measured frequency response for each model. The practical atmosphere encouraged positive and creative discussions, which resulted in new technology solutions. Through the results of discussions, the pilot team finalized the specifications for the voice emphasizing functions by combining a voice codec, digital filter, and voice signal modeling, and then commercialized the new functions that adjusted the phone’s volume adaptively to the surrounding noise.

The factors that led to success in this stage are as follows.

- The information on technologies was shared across the organizations at the generalized (scientific) level. This accelerated the coordination of the specifications.
- The “clear voice” function was planned by selecting and combining information from the in-house technology pool.

Stage 2: Adaptation of basic research to commercialization

The first generation of the voice emphasis function was introduced in the Raku-Raku phone III, released in 2003. The R&D team that joined the product development process grasped the requirements for the technologies for the next-generation model. These cross-sectional activities gave the R&D team an opportunity to join the product planning phases in the business units.

The next-generation Raku-Raku phone released in 2007 added a new function for automatic adjustment of the receiver volume. The model in 2008 was equipped with adaptive volume control in noisy environments with improved real-time processing performance. The model in 2009 improved the tolerance to non-stationary (bubble) noise such as the type that occurs in human speech.

The R&D team continued in this aspect into the final stage of product development. In the later stages, the new voice-processing algorithm required tuning to enable digital signal processors (DSPs) to be installed in cell phones, which require expertise to get past the constraints of hardware such as the affordable memory usage, programming steps, and power consumption. The R&D team conducted these tuning processes and was able to create a concrete image of the next models in the early R&D process. In other words, the R&D team was able to “synchronize” their efforts to the time scale of the business unit.

In the later stages, the R&D department and the business unit set up an official meeting based on the activities of the pilot team.

The success factors in stage 2 were as follows.

- The participation of the R&D team in the pilot team enabled an earlier start time of the R&D process.
- The R&D team collected feedback from the business unit in the pilot team. This feedback was used to plan the next model cycle.
- The unique organizational management in the official collaboration process between R&D departments and business units.

3.4 Summary of the Success Factors

This section summarizes the factors that led to the successful development.

The first key was the *generalized technologies*. Technological knowledge is accumulated and stored and is independent of particular applications. The generalized technologies were easily diffused and understood across departments, which have different areas of expertise. The second key was the utilization of pilot teams. Several departments began collaborations from within the pilot team to achieve in-depth sharing and understanding of both technologies and markets. The third key was the flexible management practices of Fujitsu Laboratories. There were a few key persons among the researchers who had advanced abilities and knowledge of the technologies, as well as the connections, action, foresight, and capability to find undiscovered problems. The flexible management contributed to Fujitsu discovering "accidental matches" among technologies and products.

In case 1, the objective of the business unit in adopting the in-house pedometer was to reduce costs. Fortunately, however, the motion-sensing functionalities brought unexpected competitiveness to the product-planning team. In the mobile phone business unit, the motion-sensing technology was a disruptive technology [19].

The next chapter describes the mechanism to convert and accumulate the technologies to be "generalized."

4 SYNCHRONIZATION PROCESS

This section discusses a new process to connect the fundamental R&D and product development.

4.1 The Role of the Synchronization Process

On the basis of the case studies described in Section 3, the authors composed a mechanism for determining the success factors of the Raku-Raku phone; this mechanism is shown in Fig. 2. The difference from Fig. 1 is the third process, which synchronizes the information on technologies between the existing R&D processes (FR) and product development (PD).

The information aggregation (IA) step is where the R&D outcomes are collected. The fundamental R&D process (FR) consisting of Research A, B, and C is the stage where the progress of each research project and the outcomes of the projects are accumulated.

In Fig. 1, the product development process (PD) is the stage in which a *request for development* is sent to a particular R&D project team that can provide concrete new technologies and realize the planned product.

The synchronization process in Fig. 2 follows different steps. The *development request* (3) is connected to IA. In the IA step, the specifications are received, and *Research A* is identified, which matches the request of the business unit.

Then, in the *application research* (5) step, the algorithm is tuned to fit the target product. If there is no technology to match the request, the business unit would look for third-party technology.

4.2 Initiation of the Synchronization Process

In the case studies, the synchronization processes were initiated without any particular management objective or systematically described procedure. To drive the model described in Fig. 2 in a practical situation, the authors developed an internal construction of the process and operation. This construction is shown in Fig. 3.

Details of the functions described in Fig. 3 are as follows.

- Generalized Technologies (GT): Features of technologies described at a "scientific level"
- Product Requirements (PR): Concrete requirements or specifications for a product in basic research
- Human Capabilities (H): The practical driving force of the "synchronization process," which includes the capabilities of researchers and engineers, as well as knowhow and implicit knowledge

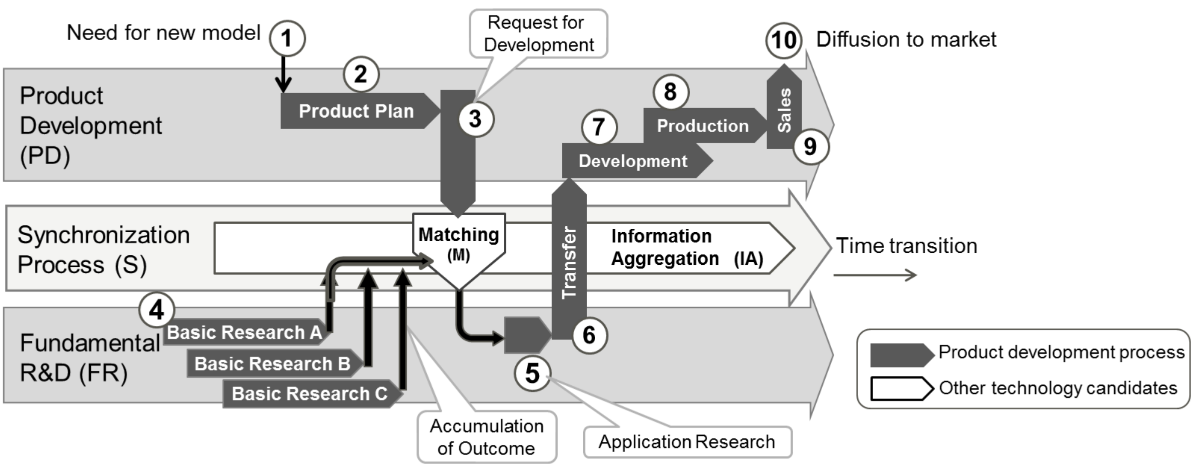

Figure 2: Core concept of synchronization process

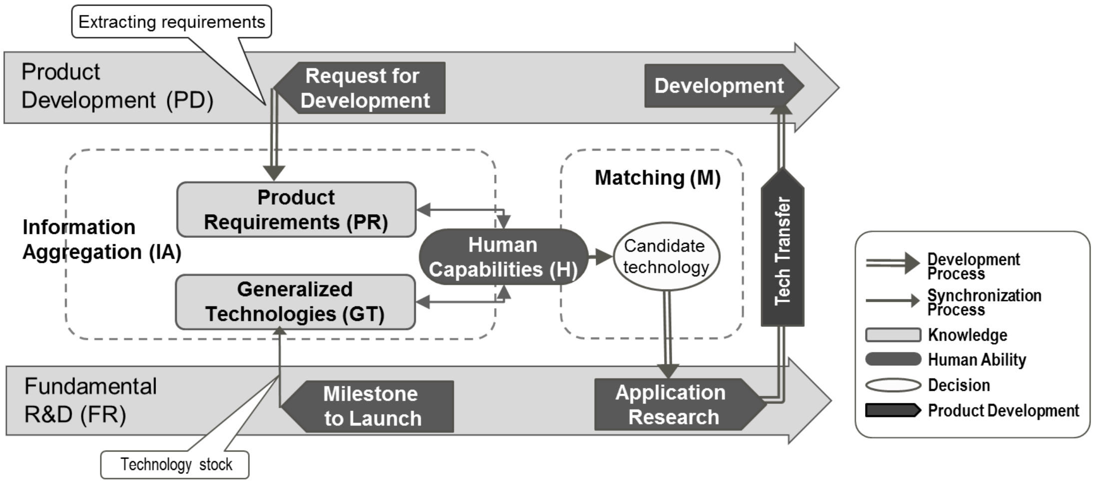

Figure 3: Internal components of synchronization process

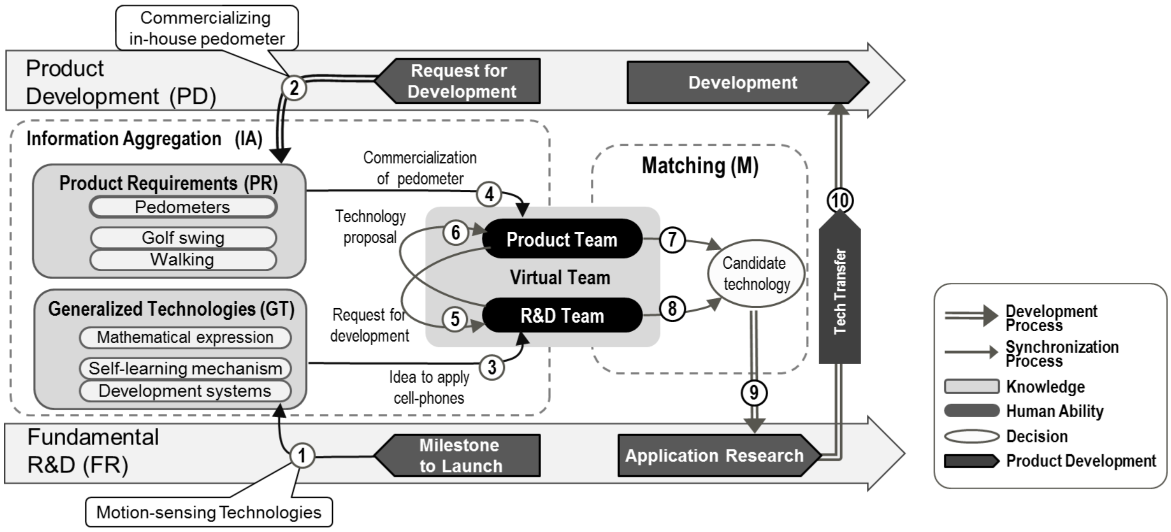

Figure 4: Synchronization process: Motion-sensing technology

The generalized technologies (GT) are based on a wide variety of researchers' knowledge. In other words, (GT) is kept in hot-standby status, ready to be connected with different unplanned applications. The potential applications in different industries could not be found only by using the technical documents, data, and patents of each R&D outcome.

To overcome the barrier differences of application categories, the (GT) should be described in a common language in order to connect the seeds and needs.

4.3 Operation of the Synchronization Process

This section describes how the synchronization process in Fig. 3 is initiated.

a. Case 1: Motion-sensing technology

Figure 4 depicts the project history of motion-sensing technology along the components of the synchronization process.

The synchronization process in this case is based on a short term (around five years). Each step is carried out in the following order.

(1) The fundamental R&D process (FR) accumulates the motion-sensing technologies describable at a scientific level into the generalized technologies (GT).
(2) The product development process (PD) registers the request for a cost-reduction strategy into product requirements (PR).
(3) The R&D team selects the appropriate technologies from the GT pool.
(4) The request for the R&D team is composed of concrete specifications.
(5) The PD requests the R&D team to develop the pedometer.
(6) The R&D team completes the development of a prototype and proposes it to the product development team.
(7) The product team sends the final candidate for the product plan to the matching team (M).

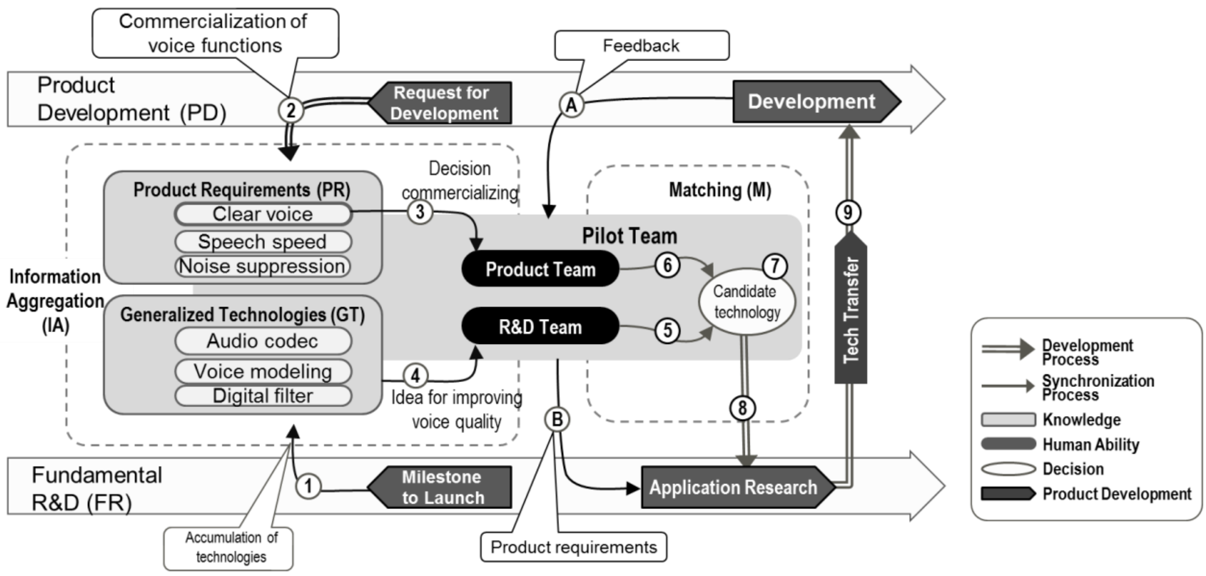

Figure 5: Synchronization Process: Voice-processing technologies

(8) The R&D team also sends the candidate technologies to M.
(9) The matching team (M) decides the final product plan and starts the product development.
(10) The fundamental R&D (FR) transfers the completed research outcome to the product development (PD) process.

A summary of the process (Fig. 4) is as follows. In the early stages of the R&D, the primary target was the robotics industry. However, the technology ended up being applied to digital cell phones. The effort of the R&D team in trying to find new application areas was the driving force in converting the technology to the new role.

As a result, this technology was selected for the product plan of the mobile-phone business unit for the new in-house pedometer and was then synchronized to the tight schedule with their sophisticated tuning technology for the motion-sensing algorithm.

b. Case 2: Voice-processing technologies

The next case involves the voice-processing technologies; the development was based on a long-term plan (several decades) in order to fully develop the synchronization process. The process illustrated in Fig. 5 was carried out as follows.

(1) In the fundamental R&D (FR) process, signal-processing technologies were accumulated as Generalized Technologies (GT).
(2) The Product Development (PD) team plans a new voice-emphasis function as a product requirement (PR).
(3) The PD determines the specifications of the new function.
(4) The R&D team selects suitable technologies from the GT to develop the voice-emphasis functions.
(5) The R&D team finishes the plan and sends it to the matching section (M).
(6) The product team finalizes the requirements and sends the finalized specifications to M.
(7) The matching section (M) finalizes the product specifications of the new voice-emphasis function.
(8) After that, the R&D team conducts application research to adapt the hardware.
(9) The functions ready to be commercialized are transferred to the PD in the business unit.

In addition to the above processes, the pilot team received feedback on the product development process after the technology was transferred (items A and B in Fig. 5).
(A) The knowhow obtained by the R&D team in the tuning stage (8) was able to be used as reference information in next generation products.
(B) The application research phase was improved by utilizing the knowhow obtained in the development of earlier generation products.

The process in Fig. 5 is summarized as follows.

The generalized technologies (GT) consist of the accumulated outcomes of voice emphasis technologies that have been compiled over the long term (since the 1980s). There was implicit knowledge of technologies; the R&D teams in this area were easily able to join the daily discussions as a cross-functional team.

Those cross-organization discussions motivated the researchers to identify new ways to improve the next product plan, which connects the technology to the product requirements. The flexible collaboration between the two organizations—the R&D team and the business unit—shortened the time-to-market of product development compared to the existing situations.

4.4 Discussion

a. Operation of the synchronization process

Figure 6 illustrates the authors' challenge in implementing the synchronization process into daily management. The most important requirement is to form pilot teams between the departments involved in the project. At this point, the exchange of persons between departments is the basic

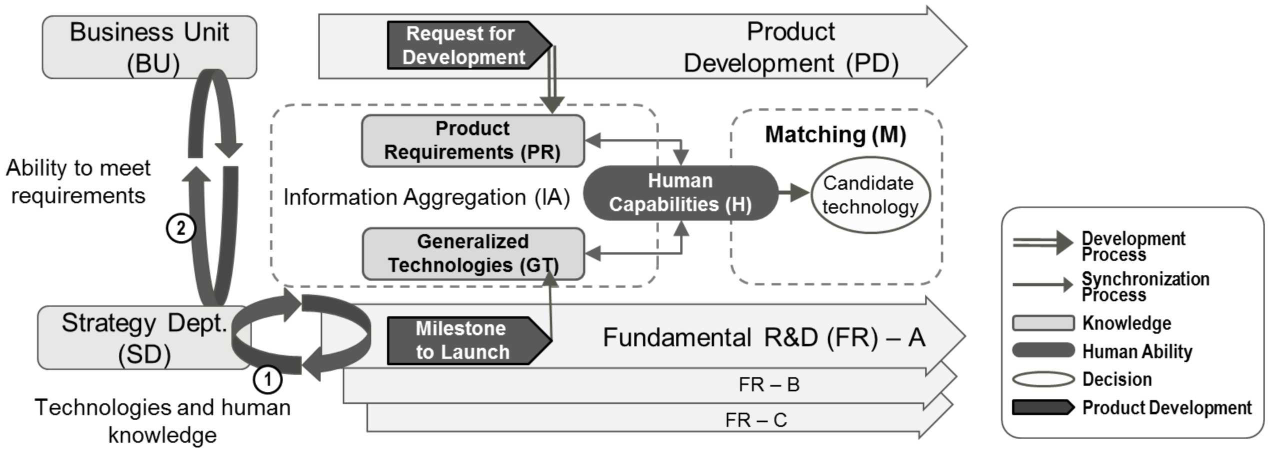

Figure 6: Synchronization process: Operation Model

strategy. In particular, the authors have been implementing the three measures and policies itemized below.

The first item is the rotation of researchers inside the R&D department (fundamental R&D and strategy dept. in Fig. 6). Researchers who represent their research areas belong to the strategy department and take part in on-the-job training to gain an overview of a broad range of technologies to give them the ability to match the technologies and potential target products (item 1 in Fig. 6).

The second item is the rotation of researchers and engineers between the R&D department and business units. This measure is aimed at improving the ability to form pilot teams (item 2 in Fig. 6).

The third item is the promotion of flexible management. Self-governing of researchers encourages a novel approach to help them meet their challenges or carry out actions based on the researchers' confidence.

The authors defined a new job title of *Innovation Director* in order to promote the policies that achieve the synchronization process.

b. The role of pilot teams

The two cases described in this paper have some differences in the relationships between departments. However, there is a common point that is initiated in the synchronization process: the pilot teams. In the "voice signal-processing" case, the planning was started within the officially organized pilot team. In contrast, the "motion-sensing technology" case had no official team at the starting point. However, there was a virtual (unofficial) pilot team consisting of two key persons who respectively belonged to the two departments of the R&D and the business unit. They shared in-depth knowledge of the technology. Practical pilot teams do not require physical rooms to communicate; they can do so using online media such as social networking services.

5 CONCLUSION

This paper discussed the classic issue occurring in high-tech industries: how to synchronize the R&D process and the constantly changing product plan of the business unit. In particular, this important issue has roots in the difference in time-scales between R&D and product development.

The authors address this issue by proposing a synchronization process to manage promising candidate technologies and concrete product plans. The latter part described the authors' challenge in upgrading the current R&D department to consolidate the synchronization process. The authors expect that this synchronization process is a continuous process that may enable a company to stay in a competitive position.

Another promising benefit from the synchronization process is that it enables the inclusion of sales and marketing knowledge, which tends to be omitted in discussions in the early stages of R&D. The driving force of this new process is the knowledge of the researchers' technologies from the viewpoint of "scientific levels," not the benefit at an application level.

The scope of this paper is the improvement of the commercialization processes within a company-wide organization. However, this concept is not limited to the user-led communities described in [20]. The authors believe these leading edge technologies can encourage such user communities to initiate innovation processes with the technologies and that the synchronization process described in this paper can contribute to the development of competitive products in a turbulent market.

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