R&D Spirits

Aiming for Top Visual Inspection Equipment through One-of-a-kind Technology

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"Let's move beyond desk-top science and develop original technology for on-site use to make real contributions to the business world." This is the R&D policy of Masakatsu Nunotani, general manager of the Vision System Division of NTT FANET Systems Corporation. The spirit embodied by this policy is giving birth to new image-sensing techniques and visual inspection equipment that are building a solid reputation in the business world. We sat down with Mr. Nunotani to hear about the technical features and future outlook of this visual inspection equipment and to ask him about his personal beliefs and goals as an engineer.

From telephone card inspection to general-purpose visual inspection equipment

—Mr. Nunotani, could you give us an outline of NTT FANET Systems and tell us about your role there?

I would be happy to. NTT FANET* was founded in 1987 with the aim of applying technology developed by NTT Laboratories to the manufacturing industry. At that time, the "convergence of factory automation and network communication" was a popular theme, and the name "FANET" was formed from letters in those words. Then, in 1990, FANET obtained control of printed telephone-card inspection technology developed by NTT Laboratories, and this marked the beginning of its vision systems business. This was followed by a period of expansion into other business areas including video systems, security equipment, and environmental equipment. More recently, FANET has built up a solutions business in partnership with NTT Communications, its top parent company. As for myself, my involvement with the development and implementation of printed card inspection technology during my days at NTT Laboratories led to my role as general manager of the Vision System Division at FANET.

—What kind of business is the Vision System Division involved in?

In short, I would say that we provide product-oriented visual inspection equipment based on image sensing and processing. In the past, visual inspection of printed matter such as telephone cards, printed wiring boards, and various types of packages was performed by the naked eye. The inspectors performing this work were highly skilled and capable, but the simple fact that they were human meant that some defects would go unnoticed and that dispersion in inspection results could not be helped. Against this background, the automation of inspection processes is a major issue with manufacturers because of its connection to quality and cost, and the equipment that we provide addresses this issue.

Our business can be broadly divided into three user categories in terms of inspection targets (**Fig. 1**). The first is general printing companies where inspection targets are telephone cards (our first inspection business) and various types of cards, labels, and seals, as well as pre-assembled packages called "blanks" for cosmetic and pharmaceutical products. The second is

* http://www.ntt.co.jp/gnavi_e/com/83.html

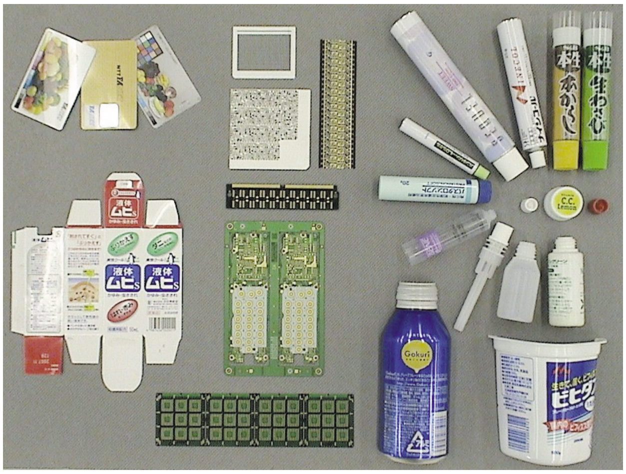

Fig. 1. Examples of inspection targets.

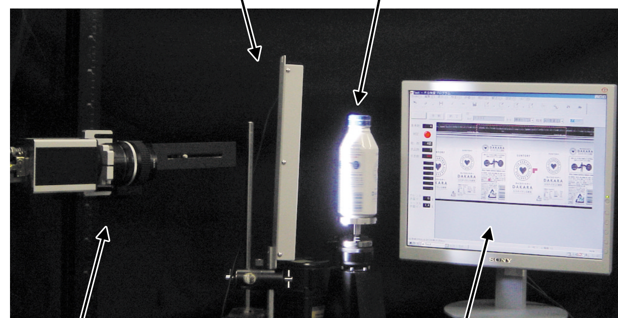

Fig. 2. Capturing images using a line-sensor camera.

electronic-component manufacturers where inspection targets are printed wiring boards (bare boards), ceramic parts, display panels, connectors, and the like. Much of our effort here focuses on the inspection of bare boards and IC-mounting boards that suffer from fine defects such as smudges, scratches, and omissions on the order of a few tens of micrometers. In this area, we developed the industry's first equipment to fully automate visual inspection that has traditionally been done by the naked eye. The third user category is container manufacturers where inspection targets are solid objects with nearly cylindrical shapes such as tubes, bottles, cans, cups, and caps. This field has been growing dramatically in recent years, and we are proud of our dominant share in the market for inspecting aluminum and plastic tubes for pharmaceutical products and foods where other companies cannot approach our quality.

—Please tell us something about the technology behind this visual inspection equipment.

The basic mechanism of visual inspection is pattern matching. The idea here is to compare images of the target item with reference images of a good product to detect differences between them. In actual inspection, though, a certain range of dispersion appears in inspection results, and we must allow for that dispersion. For this reason, we add a learning capability using multiple registration of several reference images.

We also use a line-sensor camera to shoot inspection targets (**Fig. 2**). When inspecting a solid with a curved surface like a tube using an ordinary camera, the image becomes increasingly oblique as the distance from the front view increases resulting in a highly shrinked image with uneven lighting. In contrast, a line-sensor camera captures images by scanning only the front surface of an inspection target in a linear manner while rotating the target. One complete rotation gives us a stable and continuous expanded image. On the other hand, a line-sensor camera is incapable of providing a completely undistorted image since inspection targets are not limited to flat objects and those with perfectly cylindrical shapes. Even if high-precision imaging can be performed, that distortion will prevent captured images from being compared with registered reference images. This is because image distortion itself will be treated as a defect with the result that all inspected items are judged defective. To deal with this problem, we developed a new image-alignment technique called line-block distortion reduction (**Fig. 3**). As the name implies, this technique divides an input image into a number of line blocks and overlaps and shifts those blocks as needed until they approach the reference image. The resulting image can now be compared with the reference image and any smudges or character imperfections that are found can be judged as defects. The idea here is to perfectly align the two patterns so that extremely small differences between them can be discovered. This technique can detect problems as small as fine character defects that could not be found with past equipment or by the naked eye.

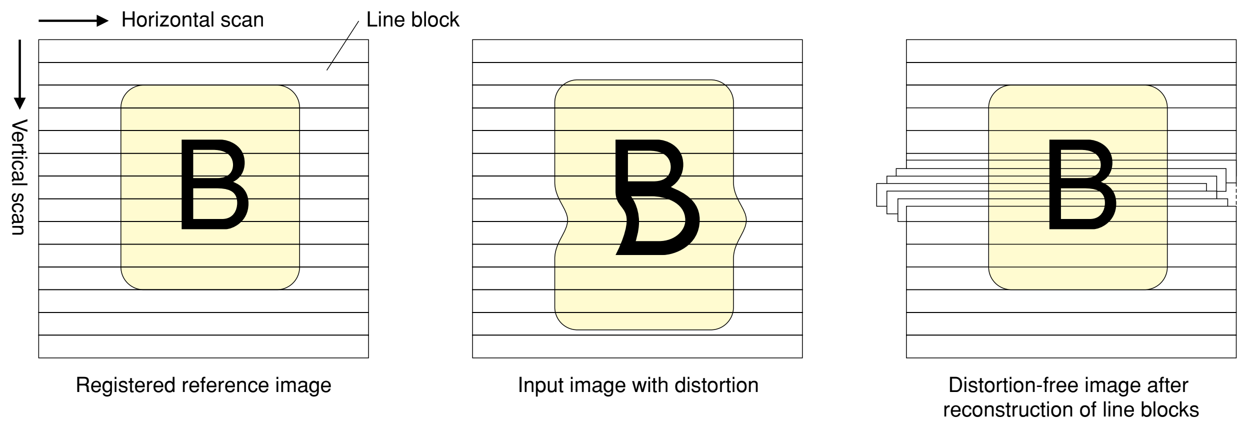

Fig. 3. Line-block distortion reduction method for pattern-matching inspection.

FANET has already obtained foreign patents for this technology in the United States, United Kingdom, and Europe. You might say that we hold a nearly global monopoly on this technology.

Development of next-generation equipment along two directions

—What benefits does FANET visual inspection technology bring to users?

Well, first and foremost would be reduced labor and improved quality, the immediate objectives of our technology. But it will also contribute to improvements in manufacturing processes through the appropriate application of inspection data. Take, for example, pharmaceutical products provided in aluminum tubes. The usage, dosage, ingredients, and other information about a product are often written in fine print. The inclusion of this information is prescribed by Japan's Pharmaceutical Affairs Law, and the presence of smudges or character defects that could prevent that information from being read or properly understood would be a serious matter. As I mentioned earlier, FANET equipment can inspect this fine print automatically. In this field, FANET's visual inspection equipment is becoming a *de facto* standard due to the demand for it from manufacturers of pharmaceutical products. Needless to say, industry's recognition of our technology gives us a great feeling of achievement.

I should also point out that the manufacture of containers for pharmaceutical products and foods is performed for the most part in clean rooms, which means that the use of human hands in visual inspection, the last step in this process, presents a problem from a hygienic point of view. How to remove the human element from clean rooms has been a major issue for manufacturers. Our equipment, which completely automates visual inspection, is playing a role in achieving that goal. Conventional naked-eye inspection, moreover, could do no more than observe—it was not capable of saving inspection data. Automated inspection, on the other hand, can save all data obtained in the inspection process. This provides a high level of traceability that, in the event of a customer claim, enables container manufacturers to make a clear determination as to whether they are to blame and to respond accordingly. Such data can also produce an immediate improvement in manufacturing yield. I think those inspection database is a great benefit to users.

—What are the R&D trends in this area, both in Japan and overseas?

To begin with, there are many competitors. In the printing and container field, I would say that Japanese manufacturers of visual inspection equipment are at the forefront, while in the electronic-components field, many overseas manufacturers have dominant positions. But a manufacturer like FANET that can cover all fields with just one type of equipment is rare. We also dominate the Japanese market for inspection of aluminum tubes and are working on overseas deals. We are confident in our ability to become a world leader in this area. At the same time, we are in an era of competition with an abundance of players ranging from long-established companies to new ventures, so we must continue to innovate and evolve in order to survive. I must admit that trends in other companies are a bit disturbing, but our plan is to develop original technology one step ahead of our competitors by identifying and meeting needs based on current and relevant user information. In this way, we aim to stay a one-of-a-kind company in this industry.

—What direction will future strategy and development take?

Our current machine embodies the second generation of our technology. The first-generation machine used color processing to inspect mainly flat objects like cards, while the second-generation machine can inspect solid objects. Compared with the first machine, the current machine has four times the processing speed, occupies one-fourth the volume, and costs half as much. The second-generation machine, however, provides monochrome processing as standard, which is a disadvantage in the face of competitors that provide color processing. Of course, color processing is available as an option, but because inspection performance is already high to begin with, the second-generation machine can perform inspections at required levels without having to use color. Nevertheless, it is obvious that our competitors are making progress, and based on our strategy of staying one step ahead before falling behind, we plan to incorporate color processing as standard in our third-generation machine. This machine will have 16 times or more image-processing capacity, 2.5 times more processing speed, and one-fourth the volume.

In addition, our third-generation development efforts are proceeding along two directions. The first is high-end oriented as in the machine I just mentioned. This is a super machine that performs image processing by dedicated hardware, all of which was developed in-house. The machine has been three years in development and its release has begun. The other direction will be low-cost while achieving functions and performance equal to that of the current machine by software means. This machine will use a general-purpose PC with a high-speed CPU and feature software processing that can flexibly apply a variety of inspection algorithms accumulated as inspection know-how over the years. The idea here is to provide a “popular model” that can find widespread use in the industry. Our lineup will therefore consist of a high-end product in a class of its own and a popular product having good cost-performance. My problem from here on is to figure out how best to market these two models.

R&D origins: The joy of creating

—Mr. Nunotani, how did you get started in R&D?

I have always been absorbed in building something. In my childhood, it was models, as a junior-high-school student, it was radios, and as a high-school student, it was audio equipment. Being this kind of person, I entered electronic engineering studies without hesitation and with many expectations. But after beginning my studies, I found that courses on electromagnetism and quantum theory with their many formulas could be quite stressful. While I can be very enthusiastic about subjects that I like and am interested in, my character is such that I can also be less than diligent with regard to subjects that don’t particularly interest me. To be more specific, I find that I can quickly understand the nature of phenomena that can be seen with the naked eye or that can be represented visually. It is this kind of phenomena that excites my interest and stimulates my creative powers. The image-sensing world that I am currently in energizes me. In this world, I can create something using the scientific and mathematical knowledge and general knowledge I obtained in school plus a small amount of specialized knowledge. At any rate, my thoughts throughout my days as a college student were that I wanted to get to work as soon as possible and feel the joy of creating. These were the origins of my current R&D activities, and my feelings in this regard have not changed one bit since then.

—What kind of R&D were you involved in at NTT Laboratories?

After entering NTT Laboratories, I became engaged in the research and development of memory devices and electronic circuits related to magnetic wire and magnetic bubbles. Although magnetic bubble memory was initially a hot topic, it was a “phantom memory” that would soon be replaced by IC memory. I was a member of the group that developed equipment at NTT that came to implement this type of memory. At that time, NTT possessed portable mechanical telephone switches that could be loaded onto a truck to support communications at times of disasters, and there was a need to replace these mechanical switches with electronic ones. Magnetic drums were then being used in electronic switches, but they were too vulnerable to vibration to be used in mobile equipment. For this reason, we decided to replace the magnetic drum with a solid-state magnetic bubble memory that was robust to vibration. This magnetic bubble memory was later adopted in high-performance electronic switches as well, and consequently this research obtained the NTT President's Prize. Even today, quite a number of magnetic bubble memories are still in operation at NTT sites.

After that project, I became involved in the development of high-capacity storage systems as a system designer. At that time, integrated magnetic-tape systems were being adopted as backup systems for general-purpose mainframe computer systems.

—How did you become involved with your present line of work?

As we entered the 1990s, personal computers and distributed processing technology had advanced to such a level that NTT began to wind down its computer development work. While wondering what I could do next, I heard talk about building image processing equipment. This was the printing inspection equipment for telephone cards. The world of image processing that makes use of hardware technology was a field where I could apply my specialized knowledge and that attracted my interest. The development of this equipment would also require not just image processing technology but also an odd assortment of peripheral technologies such as pick-up devices, lighting, mechanical mechanisms, and algorithms. That was exactly the type of development that I was experienced in. As a result of my interest, I was placed in charge of implementing the equipment and performing subsequent follow-ups. It took two years to complete equipment development, and in 1993, I was transferred to FANET with the task of turning this equipment into a full-scale business. I have been at FANET ever since.

—How do you view your work at FANET?

I look upon it as an "intelligent sport!" In a world that demands creativity, competing with a rival on the basis of technology and intelligence can be highly stimulating to an engineer's spirit. In addition, it is the customer who decides the winner, which is fair enough. Furthermore, as obtained profits can be treated as a gauge of equipment value, there is a way to quantitatively measure results. This work gives me much satisfaction.

"Fountain of knowledge"—Giving purpose to an engineer's life

—Mr. Nunotani, how will your work develop from here on?

Visual equipment is expected to see continued growth in the years to come. In particular, the global production of containers is growing and quality requirements are becoming stiffer. One issue that I will have to face here is how to deal with the wide assortment of container shapes. And in the field of electronic components, we can expect the need for visual inspection of printed wiring boards and flat panel displays to increase, and this is also something that I would like to pursue. Furthermore, from the viewpoint of developing an even wider market, I can see us cultivating new fields that can apply the technology developed in visual inspection. While we are not yet at the stage of making specific proposals, we are interested in applying visual technologies like image sensing and robot vision to a wide variety of fields including security, the environment, and social welfare.

—What are your personal aspirations at this time?

At NTT Laboratories, there is a pond called the "fountain of knowledge" where there used to be a memorial stone engraved with the words: "Let's dip from the fountain of knowledge and make it useful for the benefit of the world." I noticed these words on my first visit to NTT Laboratories before entering the company, and they have remained in my head ever since. I can relate strongly to these words that I believe reflect the history of NTT Laboratories and my own history as well. These are words that can give purpose to an engineer's career. For me, a lifelong engineer, the practical application of these words means to be active as long as possible while maintaining my curiosity, ambition, and competitiveness. My wish is to continue building things based on a scientific approach, creative ideas, and a simple-is-beautiful concept and to achieve more "industry first" commendations.

—How would you describe life at NTT Laboratories?

NTT Laboratories has been a place of learning for me in my journey to my present position. Through various R&D projects spanning a period of 20 years, I have learned much about implementation methods from my senior colleagues and manufacturing partners, especially in regards to research and implementation, equipment reliability, and quantitative evaluation. In addition, the various techniques that I was exposed to at NTT Laboratories are the roots of my scientific approach. While this approach may not be applicable to all on-site development, I am passing it on to junior researchers as an ongoing guide for performing research work.

—Mr. Nunotani, could you leave us with a message for NTT Laboratories and its researchers?

The pool of human resources at NTT Laboratories is enormous. I would hope that this pool can be applied to the extensive field of industry in addition to the communications and education fields. The achievements of NTT Laboratories accumulated over the past several decades provide researchers with a great source of potential products. I would like to see those achievements made into something useful for the world so that researchers can see the fruits of their work and feel a sense of purpose. I am convinced that if mid-level and senior researchers, who have gained much experience in their work, go out into the real world, they will encounter a wealth of possibilities. I ask all my fellow researchers to take on a fresh attitude and to step outside the traditional framework with a view to the outside world. In this regard, I think NTT's "internal venture system" and "internal recruitment system" are effective. Even FANET includes personnel that have entered the company through this internal recruitment system, and these people work as if they have found their element. I would be happy if our combined activities at FANET could become a reference for creating a new stage in research and development. Finally, I hope that NTT as a major organization can back up this effort with all its strength.

Interviewee profile

■ Career highlights

Masakatsu Nunotani received the B.S. and M.S. degrees in electronic engineering from Osaka University, Osaka, Japan, in 1966 and 1968, respectively. He joined the Electrical Communications Laboratories of Nippon Telegraph and Telephone Public Corporation (now NTT) in 1968. He was engaged in R&D of device, circuit, and system design for some kinds of magnetic memories (wires, cores, and bubbles) and mass-storage equipments (magnetic tape and optical disks). He was engaged in the development of memory equipment for NTT's data processing system (DIPS) and switching system (DEX). He is currently the general manager of the Vision System Division, NTT FANET Systems Corporation. He developed image-processing systems with an original architecture for visual inspection applications. His current interests are image sensing and machine vision.