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White Paper

Ricoh's Next-Generation Machine Vision: A Window on the Future

As the range of machine vision applications continues to expand, Ricoh is providing new value propositions that integrate the optics, electronic devices, and image processing technologies cultivated throughout the company's history. Ricoh's machine vision solutions are already being utilized in such fields as factory automation (FA), on-board systems, security, and the distribution of goods. In the future, Ricoh will continue to contribute to the social infrastructure with optical system technologies that satisfy a broad range of needs from 2D and 3D imaging to invisible and multidimensional domains.

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1. The Ever-expanding Machine Vision Market

As information and communication technology (ICT) becomes more and more crucial to the social infrastructure, systems that enable society to function more smoothly are increasingly needed. An ICT infrastructure that solves the many day-to-day inconveniences and allows each individual to fulfill his or her potential is called for. Support for safety and assurance is one such example. Machine vision is a technology that meets these expectations by processing visual information to control the movement of machinery. Currently, beyond being used in industrial manufacturing in its traditional role of factory automation (FA), machine vision is also expanding its scope to the fields of security, medicine, and agriculture. Its adoption is being accelerated by the introduction of new image sensing devices and the growth of computing technologies, including communication. As various systems head towards further automation, machine vision is being advanced to a point where it will not only serve as a replacement for human vision, but also handle invisible and multidimensional information.

2. Ricoh's Achievement with Machine Vision

Since the late 1970s, Ricoh has put great effort into developing advanced automated production facilities, and has accumulated a wealth of machine vision-related technological expertise via activities such as the installation of sensor modules for product inspection, for example. While advancing the development of optical modules for accelerating internal automation, Ricoh has also dedicated a portion of its achievements to external FA and on-board systems manufacturers, and has earned a solid reputation in the machine vision market. Given the increasing importance of machine vision in a variety of fields, Ricoh has accelerated its involvement in the technology through its purchase of the PENTAX brand of machine vision lenses and other optical technology assets in 2011. The company also launched the Optical Systems Business Group in April 2012. Further, in October 2014, a new company, Ricoh Industrial Solutions Inc., commenced operations, consolidating technologies and human resources in the areas of optics, image processing and electronic components, which had previously been spread across the Ricoh Group. The new company has thereby been contributing to the

strengthening and expansion of the Ricoh Group's industrial products business.

3. Ricoh's Technology Assets that Enable Progress in Machine Vision

Since its founding in 1936, Ricoh has focused on imaging equipment for business and consumers, and has delivered a series of revolutionary products to the marketplace. All have been thoroughly grounded in the customer's needs and perspective. Beyond being agile enough to meet the demands of our customers, our mission also reflects market trends. In 1977 we led the industry with the first proposals for office automation (OA), showing the way to the future of office equipment. Since then, we have continually pursued the creation of new value while maximizing the potential of the latest technology in a range of sectors such as optics, material science, mechatronics, image processing, electronic devices, communication, software, and manufacturing. Based on these achievements, Ricoh is now providing high-performance, reliable optical modules to customers in a wide array of fields such as FA, automotive, security, and logistics.

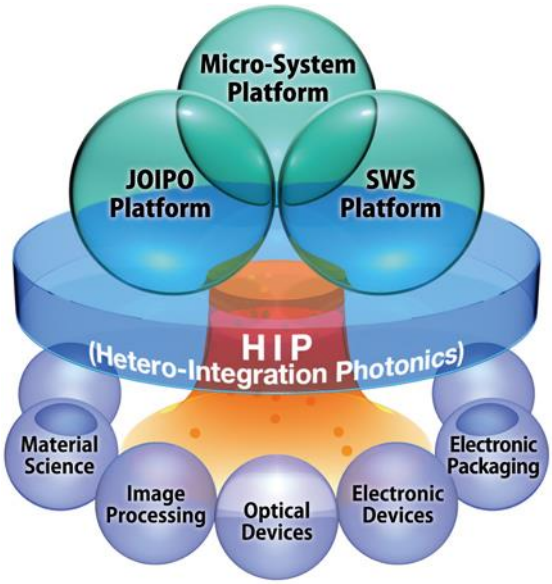
4. Ricoh's Strengths in Machine Vision Development

Machine vision from Ricoh stems from research into cutting-edge and unique technology, which enables us to provide innovative products for our customers. In addition, we emphasize close collaboration with our customers in order to make the achievements of our R&D divisions available to our customers as quickly as possible. The goal for Ricoh machine vision is to develop intelligent technology that not only operates according to user instructions, but can also rapidly assess the situation and take appropriate action without human involvement. In other words, Ricoh is committed to innovating in such fields as social support, where safety and assurance are key, and flexible manufacturing, where automation is difficult and reliance on human workers is hard to avoid. Moreover, we are aiming to actively break new ground in fields where machine vision has not yet been applied.

5. Technology Platforms Supporting the Development of Ricoh Machine Vision

Ricoh's core technologies that have supported a wide array of business sectors include advances in optics, image processing, electronic devices, electronic packaging, and material science. In preparation for machine vision development, Ricoh has re-organized these core technologies, by considering their marketability and future trends, and restructured them into three technology platforms.

At Ricoh the optical system architecture that unifies the three platforms is known as Hetero-Integration Photonics (HIP), and is making inroads in the machine vision market leveraged by the HIP architecture. In the machine vision market, because of its interdisciplinary nature, it is important not only to develop optical modules based on the rich technological assets of HIP, but also to strategically address the current demand and future market trends. HIP is an architecture for next-generation machine vision to serve our customers worldwide utilizing a variety of Ricoh assets ranging from R&D to product design, production, and customer service.



Optical system architecture: HIP conceptual diagram

These three platforms are explained below.

5.1. Joint Optics / Image Processing Optimization (JOIPO) Platform

Advanced image systems are not achieved by simply pairing high-quality lenses with high-performance sensors. The key to image system design lies in the advancement of lenses and various other optical components, as well as the development of image processing algorithms that coordinate these components. Ricoh has established a JOIPO platform for designing systems that integrate the lens optics and electronic image processing subsystems, which have traditionally been designed separately. JOIPO optimizes the optics parameters and image processing parameters as one whole module to maximize performance. This represents a fundamental revolution over the traditional development method, in which the output is adjusted with image processing design after first waiting for the results of the optical design. Thus it has become possible to develop the high-performance, ultra-compact, and ultra-lightweight imaging systems demanded for machine vision such as the extended-depth-of-field cameras and stereo cameras discussed later.

* See The Fusion of Optics and Digital Image Processing: “JOIPO Platform” for more detailed information.

5.2. Sub-Wavelength Structure (SWS) Platform

As the machine vision market grows, new optical modules are being developed. The possibilities of machine vision could be expanded even more by visualization of invisible information. A promising technology for such devices is sub-wavelength structure (SWS). Ricoh has been working on practical applications for SWS technology since the 1990s; applications such as pickup devices for optical discs have already been brought to market. The SWS platform was built on the back of such technological achievements, and it will serve as a key technology for machine vision development. By combining the SWS optical devices with image sensors, it will be possible for these electronic eyes to sense polarization differences that are invisible to the human eye, for example. Also, because SWS devices operate over

a wavelength band from the visible spectrum to infrared, information on amplitude (brightness), wavelength (color), and polarization can be detected all at once. Ricoh provides innovative machine vision products by maximizing the potential of the SWS platform.

5.3. Micro-System Platform

Ricoh develops various microprocessing units (MPUs) built into in-house imaging equipment and digital devices, as well as hybrid integrated circuits and micro-electro-mechanical systems (MEMS). Building on these achievements, Ricoh is establishing a Micro-System platform with the aim of expanding the optical technology in combination with the electronic devices at its core. In addition, our rich knowledge of material science and its processing technologies is one of our precious assets. By taking advantage of our Micro-System platform, we are making advances in the high-precision packaging of optical components required for devices. Examples include the multi-spectroscopic cameras and polarization cameras discussed later.

6. The New Value Provided by Ricoh Machine Vision

With machine vision developed under the HIP architecture, Ricoh will provide customers with new value by expanding the imaging region. By fusing the JOIPO, SWS, and Micro-System platforms, Ricoh will provide optical modules whose performance comes ever closer to that of the human eye. In addition, it will forge a new machine vision environment that can capture information in domains inaccessible to human vision. As a result, automation will become possible in 2D and 3D as well as invisible and multidimensional imaging in situations where reliance on human workers has so far been unavoidable. Examples of these technologies are presented below.

6.1. 2D Imaging

In the 2D domain, Ricoh is pursuing better image quality, including high definition, while also enabling the detection of information that has been difficult for conventional optical modules. Typical optical modules are as follows.

・Extended Depth-of-field Camera

With a camera that extends the depth-of-field without sacrificing spatial resolution or the amount of transmitted light, it is possible to clearly recognize objects without adjusting parameters such as the focal length or angle. Because autofocus components are unnecessary, extended depth-of-field cameras are highly stable and reliable, and make it possible to realize an ultra-compact, low-cost machine vision environment. Application is possible in a variety of fields such as FA, distribution, security, public infrastructure inspection, and personal use.

Imaging result from traditional camera. Front QR code is unreadable.

Imaging result from extended−depth- of-field camera. Both front and rear QR codes are readable.

* See Extended Depth-of-field Camera for more detailed information. Product information is here.

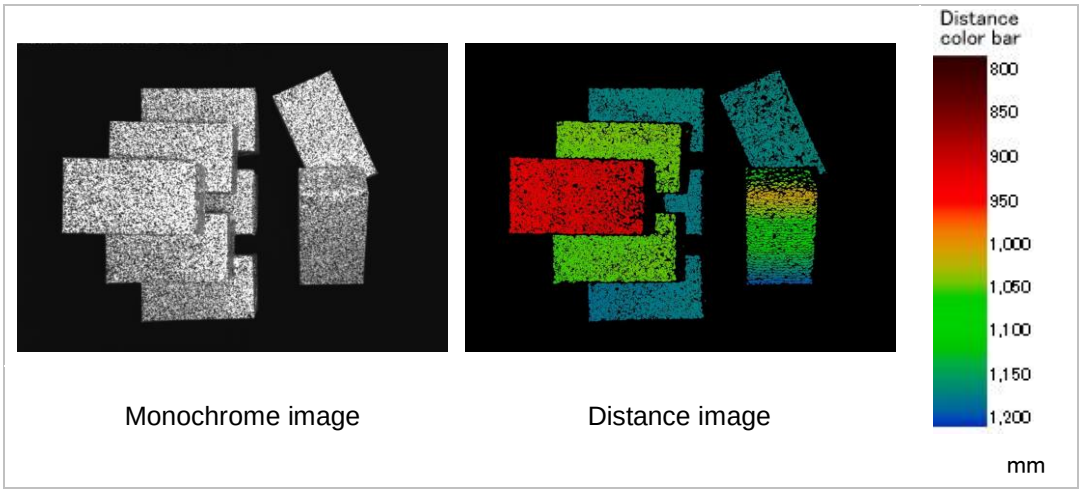
6.2. 3D Imaging

By using optical modules that can capture their surroundings in 3D, it is possible to obtain information such as an object's position, shape, and state. It is also possible to detect moving objects in addition to still objects. Optical modules suited to the 3D domain include the following.

・Stereo Camera

A stereo camera detects distance using two CMOS image sensors. Ricoh has succeeded in producing stereo cameras that are unprecedentedly precise by fusing several accumulated technologies: optical technology, image processing technology and packaging technology. Further, image processing and parallax computation processing are optimally installed on a chip inside the stereo camera, which makes it possible to output accurate 3D information fast and in real time. Application is possible in industrial fields such as FA, logistics, security, and public infrastructure inspection.

Exterior of stereo camera



Monochrome image　　Distance image

* See Stereo Camera for more detailed information. Product information is here.

6.3. Invisible and Multidimensional Imaging

Optical modules for machine vision have so far been available with the aim of substituting or supplementing human vision. As a result, it has been possible to reduce the burden on human workers while still improving product quality. However, automation and cost savings are already reaching their limits with such substitute optical modules. With diversified low-volume production, for example, it is exceedingly difficult for conventional optical modules to recognize differences in size, shape and material quality; creating a program to handle the task is not trivial. Consequently, using human labor to cover misrecognitions has been unavoidable. To solve such problems, Ricoh is committed to developing innovative optical modules able to detect multidimensional information that cannot be handled with conventional optical modules, as well as invisible information that cannot be perceived by the human eye. Optical modules suited to the invisible and multidimensional domains include the following.

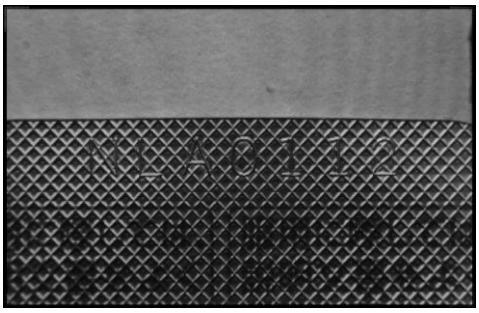
・Multi-spectroscopic Camera

A multi-spectroscopic camera is an optical module that can acquire spectral information from a subject. Although systems using interchangeable color filters and prisms have been established as typical color image recognition modules, with interchangeable color filters, the required filter change poses a barrier to real-time multispectral imaging. With the prisms, it is difficult to make the camera more compact. Ricoh multi-spectroscopic cameras use optical devices that can acquire plural spectral information in a single snapshot, together with an image processor that generates an image for each spectral information. As a result, the spectral distribution and chromaticity for particular wavelengths can be computed in real-time. This makes it possible to precisely acquire the desired spectral information. In addition, spectral information can be acquired with a device similar in size to a conventional FA camera. Beyond detecting subjects hard to distinguish from each other, our multi-spectroscopic cameras can be used to inspect objects whose states change over time and to detect foreign matter. Possible fields of application include FA and the food, pharmaceutical, agricultural, and security industries.

* See Multi-spectroscopic Camera for more detailed information.

・Polarization Camera

A polarization camera can acquire polarization information from a subject. Acquisition of polarization information with a normal camera is usually been done with a mechanically-rotating polarization filter in front of the camera. However, the Ricoh polarization camera captures polarization images in real-time without mechanically adjusting the polarization filter or other parameters. Our polarization cameras can be used to recognize hard-to-distinguish differences between transparent surfaces and non-transparent surfaces, and to detect information on the surface orientation of single-colored objects. Possible fields of application include FA, security and environmental industries.



Brightness image

Polarization image

With the polarization image, distinguishing a stamped mark on a pill-package is possible.

* See Polarization Camera for more detailed information.

7. A better Society Empowered by Ricoh Machine Vision

Along with providing high-performance and high-quality optical modules for fields such as FA, automotive, security, and the environment, we are advancing machine vision development setting safety and assurance as key focus areas.

In the industrial field, including FA, we have been providing machive vision with

automation to create higher added value and even greater cost savings. For example, we commercialized a picking system “RICOH RL seiries” (only in Japan), which employs the stereo camera as the eyes for picking robots, and automated processes from selection of parts to alignment. The system can handle parts in various sizes in the processes, offering improvements in cost reduction and productivity in a field where automation in production lines had been difficult.

Furthermore, we are accelating innovation in building better, safer and assured social infrastructure. One example we have developed is a super-wide-angle stereo camera, which functions as the eyes of a drone (small unmanned aerial vehicle). The drone system uses the super-wide-angle stereo camera to estimate its position and obtain information on obstacles, such as those inside warehouses and other large facilities that cannot receive GPS signals, to enable a stable automatic flight. Another example we have been developing is machine vision technologies to act as eyes in public infrastructure inspection systems. This can facilitate inspection from a moving car, making it especially easy for public infrastructure such as roads and tunnels. The solution includes a road inspection system which measures cracks and ruts on roads by using a stereo camera capable of measuring distances very accurately, and a tunnel inspection system which performs wall inspections inside tunnels by using an extended depth-of-field camera capable of clearly capturing a subject in-focus in an extended range of distances.

We are aiming to actively develop intelligent solution services in such fields where reliance on human workers is hard to avoid, and where machine vision has not yet been applied. Wherever people interact with machines and systems, Ricoh will be there to create a better and more comfortable interaction.

Revision History

Ver1.0.0	*2012/12/05*	*first edition released*
Ver1.1.0	*2013/12/02*	*revised*
Ver1.2.0	*2014/12/16*	*revised*
Ver1.2.1	*2016/09/30*	*revised*