産業用カメラ「LuFact」シリーズの開発

笹井義史，大河内潤，中野雅弘，吉岡玄史，金丸謙介，本　佳弥，近藤俊介

Development of Industrial Camera “LuFact” Series

Yoshifumi SASAI, Jun OKOCHI, Masahiro NAKANO, Genshi YOSHIOKA,
Kensuke KANAMARU, Yoshiya MOTO and Shunsuke KONDO

「LuFact（ルファクト）」は，ニコンが長年コンシューマー向けカメラ製品で培ってきた信頼性の高い技術を搭載した産業用カメラである．2022年７月に GigE Vision に対応した A1000-G，USB3 Vision に対応した A1000-U と高感度200万画素のモノクロカメラ AH020-MR，800万画素のモノクロカメラ AH080-MR の２種類のカメラヘッドを発売した．また，2023年３月に GigE Vision，および，AI 処理が可能な処理ユニット A2000-G と800万画素のカラーカメラ AH080-CR，500万画素のグローバルシャッター方式のモノクロカメラ AH050-MG，CH050-MG の３種類のカメラヘッドを開発した．
ここでは，LuFact シリーズの開発要素について説明する．

“LuFact” is an industrial camera equipped with highly reliable technology that Nikon has cultivated over several years under its consumer camera product category.
In July 2022, A1000-G, A1000-U, and two types of camera heads, AH020-MR and AH080-MR, were released. In March 2023, we developed the A2000-G and three types of camera heads: AH080-CR, AH050-MG, and CH050-MG.
This section describes the development elements of the LuFact series.

Key words 産業用カメラ，GigE ビジョン，EtherNet/IP，高信頼性，エッジコンピューティング
industrial camera, GigE Vision, EtherNet/IP, high reliability, edge computing

1 Introduction

“LuFact” is an industrial camera that is equipped with highly reliable technology that Nikon has cultivated over many years in consumer camera products. In July 2022, A1000-G/A1000-U and two types of S-mount camera heads AH020-MR and AH080-MR were released. In March 2023, the AI processing unit A2000-G, two types of S-mount camera heads AH080-CR and AH050-MG, and one type of C-mount camera head CH050-MG were released (Fig. 1).

Here, we explain the development elements of the LuFact series.

2 Compact and separate design

The camera head with the image sensor was separated from the image processing unit with the image processing Integrated Circuit (IC) to achieve an ultra-compact camera head. The dimensions of the S-mount model camera head are 20 mm × 20 mm when viewed from the mount surface. However, through strategic optimization of the board layout and component placement, it remains fully compatible with 1/1.8-inch 8-megapixel image sensors (Fig. 2). This achievement in miniaturization also enhances the adaptability of the camera head for integration into exist-

Fig. 1　LuFact series

Fig. 2　Camera head (S mount)

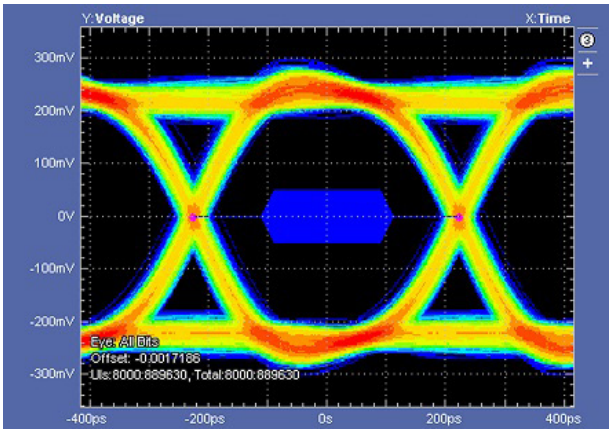

Fig. 3 Differential signal eye pattern (cable length: 10 m)

ing equipment and production lines.

Moreover, advancements in cable design allow for the extension of the cable length between the camera head and the main unit up to 10 meters. This accomplishment is facilitated by an embedded clock type differential signal, engineered to support long-distance transmission. The incorporation of optimized wiring patterns and an equalizing function further counteracts the signal attenuation inherent to extended distances (Fig. 3).

A significant benefit arises from the segregation of the image processing unit, a notable source of heat generation, from the camera head. This separation significantly reduces temperature rise in the camera head, preventing potential instances of overheating-related camera stoppages. Furthermore, this feature renders the camera head suitable for attachment to devices where temperature-related impacts must be minimized or avoided.

3 Supported communication standards

With LuFact, multiple communication standards are supported, and they can be used according to the customer's usage environment and purpose.

Currently, the communication standards supported by the A2000-G are 1. GigE vision standard, 2. RTSP/RTP streaming standard, and 3. EtherNet/IP standard. Here, we describe each standard and its application in A2000-G.

3.1. GigE vision standard

The GigE vision standard is an image transfer standard that is standardized by the Association for Advancing Automation (AAA), an automation ecosystem industry group in the United States. It is mainly intended for applications to industrial digital cameras and their counterparts (e.g., application software running on Personal Computers (PCs). Gigabit Ethernet was used as the lower layer of the communication protocol, facilitating the use of low-cost standard cables and network equipment, as well as long-distance, high-speed image transfer. Standard-compliant products can be interconnected, and hundreds of standard-compliant products are offered by companies worldwide.

The GigE vision standard consists of three parts: device detection, GigE Vision Control Protocol (GVCP), GigE Vision Stream Protocol (GVSP), and format (Fig. 4). GenICam and SFNC were also adopted as software interface standards.

The A2000-G is set so that GigE standard-compliant application software automatically starts when shipped from the factory. Moreover, we provide LuFact Utility application software that runs on a PC, enabling users to operate the A2000-G as a GigE standard camera immediately after purchasing the A2000-G.

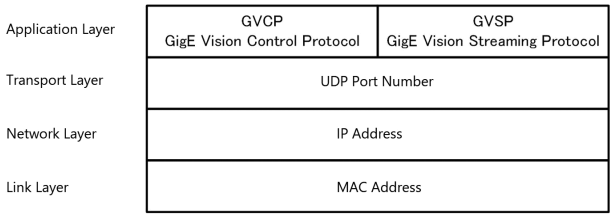

Fig. 4 GigE Vision

3.2. RTSP/RTP Streaming standard

RTSP stands for “Real Time Streaming Protocol” and is a streaming control protocol that is standardized as RFC2326 by Internet Engineering Task Force (IETF). RTP is an abbreviation for “Real Time Transport Protocol”. RTP is standardized as RFC3550 by IETF, and is a data communication protocol that provides real-time delivery of data streams such as voice and video. UDP is used for the lower streaming layer (Fig. 5).

RTP is used together with RTCP, and the main roles of RTP are jitter compensation and data loss detection.

The A2000-G uses the RTSP/RTP protocol for the LuFact Streaming application software. RTSP involves the implementation of only the required methods (DESCRIBE, OPTIONS, PLAY, SETUP, TEARDOWN) on TCP/IP (settings related to images are implemented in a different way).

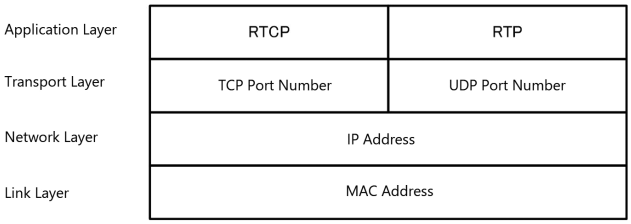

Fig. 5 RTSP/RTP

Notably, RTP has no audio, and the images are transferred after applying the MPEG/AVC (H.264) encoding format.

3.3. EtherNet/IP Standard

EtherNet/IP represents an industrial networking standard built upon the foundation of Ethernet, designed to offer simultaneous connectivity for Internet, enterprise, and industrial automation applications. The architecture incorporates a two-layer structure, with the application layer employing the Common Industrial Protocol (CIP), while the lower layer employs the Transmission Control Protocol (TCP) and User Datagram Protocol (UDP) for data transmission (Fig. 6).

EtherNet/IP is versatile, serving various communication needs across control and information levels. Beyond EtherNet/IP's scope, CIP encompasses additional protocols such as CompoNet, catering to sensor and actuator communication, and DeviceNet, tailored for device-level interactions. These protocols are accompanied by features like communication security, time synchronization, and multi-axis motion control. Leveraging the CIP network's capabilities, developers can create application software capable of comprehensively managing entire systems.

Managing and certifying the CIP standards, including EtherNet/IP, is the responsibility of the Open DeviceNet Vendors Association (ODVA), a non-profit organization headquartered in the United States. Broadly speaking, two types of communication are supported: implicit communication, which is periodic communication; and explicit communication, which allows communication at arbitrary timing such as events. It is characterized by its high compatibility with TCP/UDP/IP compared to other industrial networks.

The A2000-G adopts this EtherNet/IP communication standard and uses EtherNet/IP for communication with a programmable logic controller (PLC).

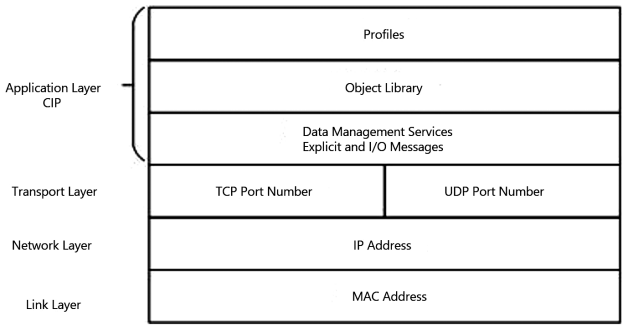

Fig. 6 EtherNet/IP

4 Performance in dark settings

The AH020-MR camera head is equipped with a back-illuminated monochrome high-sensitivity image sensor with 2.13 effective megapixels. A small amount of light can be converted into electrical signals even in environments where lighting equipment cannot be installed. Notably, it is possible to acquire a clear image without installing an illumination device while suppressing noise amplification by gain (Fig. 7).

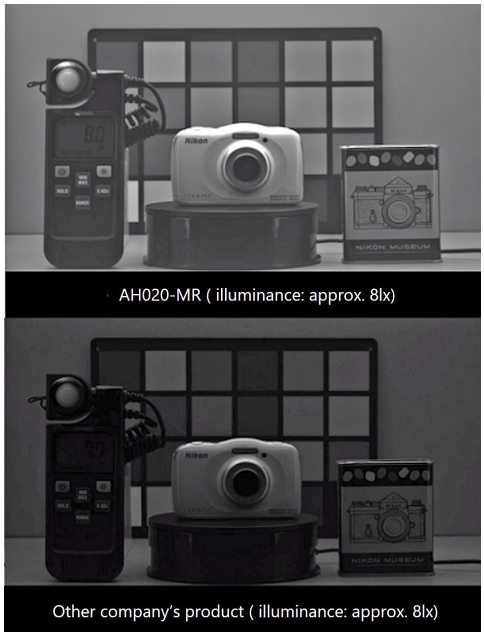

Fig. 7 AH020-MR performance in dark settings

5 High reliability

Industrial cameras must operate continuously 24 hours a day, 365 days a year. Hence, temperature is one of the factors that must be controlled for stable operation. We repeated thermal simulations so that the unit could withstand high-load image processing, and determined the shape of the heat sink and size of the cooling fan (Fig. 8). Stable operation was achieved without stopping operation owing to overheating protection (thermal shutdown), even at maximum load.

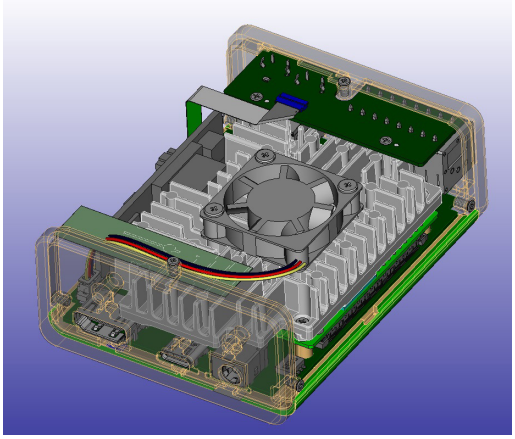

Fig. 8 High reliability

Fig. 9　Inspection of missing parts

6 Edge computing

The LuFact A2000-G incorporates a Central Processing Unit (CPU) with Artificial Intelligent (AI) capabilities, enabling it to inspect missing components without the need to transfer image data to a separate PC or server (Fig. 9). Integration of a barcode reader allows for the retrieval of serial numbers, which can then be correlated with inspection data. Should a defect be detected, the system can trigger actions such as activating PLCs or illuminated signal lights to promptly indicate abnormalities.

7 Conclusion

The LuFact series serves a dual purpose, catering not only to traditional industrial cameras but also facilitating inspection through edge computing. By leveraging Nikon’s image analysis technology and AI capabilities, we aim to contribute to the realization of smart factories. Lastly, we extend our heartfelt appreciation to the numerous individuals who have played a pivotal role in the development of the LuFact series.

笹井義史　Yoshifumi SASAI
デジタルソリューションズ事業部 第二開発・技術部
2nd Development Department
Digital Solutions Business Unit

大河内潤　Jun OKOCHI
デジタルソリューションズ事業部 第二開発・技術部
2nd Development Department
Digital Solutions Business Unit

中野雅弘　Masahiro NAKANO
デジタルソリューションズ事業部 第二開発・技術部
2nd Development Department
Digital Solutions Business Unit

吉岡玄史　Genshi YOSHIOKA
デジタルソリューションズ事業部 第二開発・技術部
2nd Development Department
Digital Solutions Business Unit

金丸謙介　Kensuke KANAMARU
デジタルソリューションズ事業部 第二開発・技術部
2nd Development Department
Digital Solutions Business Unit

本　佳弥　Yoshiya MOTO
デジタルソリューションズ事業部 第二開発・技術部
2nd Development Department
Digital Solutions Business Unit

近藤俊介　Shunsuke KONDO
デジタルソリューションズ事業部 第二開発・技術部
2nd Development Department
Digital Solutions Business Unit