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Automatic Lift System for Maintenance of CCTV Cameras

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The size of the Korean closed-circuit television (CCTV) camera market has grown by an average of 11% per year since 2011. As of 2015, there were approximately 740,000 camera units in operation in the public sector and 7.8 million units in operation in the private sector. For the maintenance of CCTV cameras installed at high places, there are two main maintenance methods: maintenance utilizing a ladder with two or more operators and maintenance utilizing a cherry-picker for high places and roads where the use of ladder is not possible. Maintenance work in the air is necessary for both methods. However, these maintenance methods incur labor costs for two or three operators, as well as additional vehicle rental costs, and require preparation time for road control, ladder installation, etc. Furthermore, they introduce the risk of falling, which had the second-highest incidence rate of 15.67% among all industrial accidents as of 2015. To address these issues, in this study, an automatic lifting system was developed to take down CCTV cameras installed at high places. The system consists of a motor driver, sensors to identify the locations of lifted cameras, electrical interface that connects the system and cameras, and control unit to control the system. The system is expected to facilitate safe on-ground maintenance of CCTV cameras installed at high places and improve the economic and time efficiency of maintenance work.

Keywords: CCTV camera; lifting equipment; maintenance; high place work; industrial accident

I. INTRODUCTION

A. Motivation for this study

Advancements in information and communication technology have facilitated the convenient and rapid collection of information. In particular, image information is considered to be highly useful information. Various types of cameras are utilized to obtain image information and the role of closed-circuit television (CCTV) cameras, which are employed for security, surveillance, and situational awareness, is rapidly expanding. The value of the global CCTV camera market was 105-billion dollars in 2011 and 202-billion dollars in 2016, with an expected average annual growth of 14%. The value of the Korean CCTV camera market was 1-trillion, 93.6-billion won in 2011 and 1-trillion, 691.2-billion won in 2015, showing an average annual growth of 11%. One can see that CCTV cameras are widely installed and utilized in daily life (Jeon, 2012; Lee *et al.*, 2017).

However, when CCTV cameras operate for long periods of time, many issues tend to arise, such as deterioration in image quality caused by foreign substances infiltrating the camera lens, performance degradation as a result of the camera and associated devices becoming obsolete, and malfunctions caused by external electrical or physical shocks. Therefore, regular maintenance is required for CCTV cameras to function properly and the CCTV Maintenance Guidelines published by the Ministry of Land, Infrastructure, and Transport recommend monthly CCTV maintenance (ITS Operation Manual). The traditional methods for CCTV camera maintenance are presented in Figure 1.

Traditional maintenance work consists of maintenance utilizing a ladder with two or more operators, maintenance utilizing a cherry-picker, or maintenance by manually taking down a CCTV camera pole. However, these maintenance methods introduce the risk of falling as operators perform maintenance at high places and

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incur labor costs for two or more operators, as well as vehicle (cherry-picker) rental costs. Additionally, performing maintenance at high places is very inconvenient and time consuming.

Figure 1. Traditional maintenance work practices

B. Study purpose and description

1. Falling accidents

Regarding installation locations, indoor CCTV cameras are typically installed at a low height of 2–3 m from the ground, but outdoor cameras are typically installed much higher (10 m or higher) and are often installed in areas that are hard to access for operators. To perform maintenance work on these CCTV cameras, operators must utilize a ladder or cherry-picker, which introduces a high risk of falling accidents. According to the Industrial Accident Statistics of 2015, published by the Ministry of Employment and Labor, falling accidents had the second-highest incidence rate of 15.67% among all industrial accidents (MoEL, 2015).

2. Inefficiency of maintenance work

For maintenance at high places, extra time is required to prepare, install, and control a ladder or cherry-picker. Additionally, maintenance work on a ladder or cherry-picker slows down maintenance speeds compared to those on the ground because of spatial restrictions and instability of posture. Furthermore, maintenance is impossible at night or in bad weather, leading to delays in maintenance.

3. Economic loss

For maintenance utilizing a cherry-picker, the vehicle must be rented and there must be operators for vehicle control, road control, etc. For maintenance utilizing a ladder, it is recommended in the Safety and Health Guidelines of the Korea Occupational Safety & Health Agency (Article 24 of the Regulations on Occupational Safety and Health) that operators must work in pairs of two for safety (KOSHA, 2017). This means the maintenance of cameras at high places incur labor costs for two or more operators.

4. Study description

In this study, to address the issues in traditional CCTV maintenance methods, a novel maintenance system was designed and developed. The proposed system consists of a motor driver to take down CCTV cameras at high-places, sensors to identify the locations of lifted cameras, electrical interface to connect the system and cameras, and control unit to control the system. The proposed system is illustrated in Figure 2.

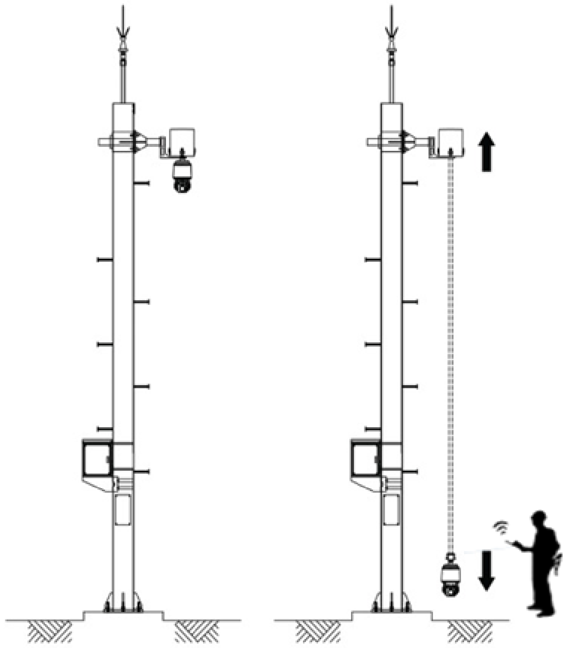


Figure 2. Automatic lift system for the maintenance of CCTV cameras

II. CCTV CAMERA INTERFACE

To lift CCTV cameras utilizing the method proposed in this paper, an electrical interface that connects the lifting system to the cameras is required. Such an interface requires analysis of the image output methods and control methods of each camera.

A. *Image output methods*

The image output methods of CCTV cameras are listed in Table 1. CCTV Camera technology trends have evolved from early analogue low-resolution standard definition (SD, 720×486) and high definition (HD, 1920×1080) interfaces to serial digital interfaces (SDIs). SDI methods transmit image signals digitally, meaning they are able to transmit clear HD images without signal loss caused by attenuation or external noise, which is often observed in analogue methods.

Table 1. CCTV camera technology trends

Category	SD/HD	SDI	IP
Image handling method	Analogue	Digital	Internet-based digital
Image transmission	Coaxial cable	Coaxial cable	UTP cable
Spec.	NTSC, PAL	SMPTE 259M/292M/424M	ONVIF

Additionally, the use of internet protocol (IP) cameras through IP networks, rather than traditional coaxial cables, is expanding to the remote monitoring of HD images and camera control (Jee, 2010; Park, 2014).

With recent advancements in internet-of-things technology, many sensors and devices are handling data management through the internet. However, the transmission of image data through a network requires high bandwidth. Therefore, image data is compressed prior to transmission (Santoso *et al.*, 2018; Lama & Kwon, 2013). The image data from IP cameras are handled by a network video recorder through a network. Additionally, the monitoring and control of cameras are made possible through the internet by utilizing smart devices, such as smartphones and tablets (Lee & Oh, 2013).

B. *Terminal connection method*

The external interface terminals of CCTV cameras consist of image output terminals, a control input terminal, and power terminal, as shown in Figure 3. The image output terminal is a Bayonet–Neill–Concelman(BNC) terminal. This type of terminal typically utilizes coaxial cables to transmit images. In this case, two lines are required to provide a ground connection for image transmission. RJ45 terminals are also utilized for IP cameras. Such terminals have recently become very popular and four of the eight available lines are essential for CCTV camera operation. In the case of IP cameras with power over Ethernet, because both images and power are transmitted through an RJ45 terminal, a total of six lines are utilized with four lines for data and two lines for power (Lee, 2015).

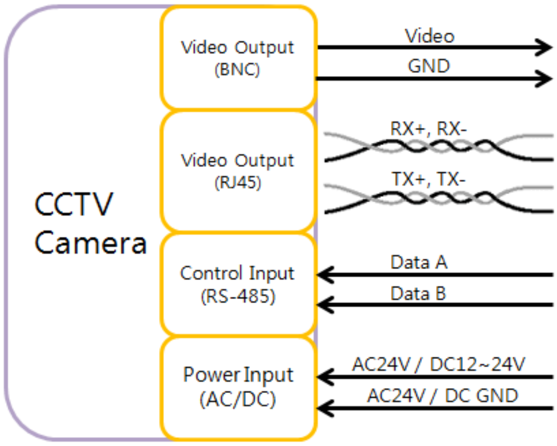


Figure 3. CCTV camera external interface terminal

For the input terminals for functions such as camera settings and pan/tilt/zoom, an RS-485 terminal is utilized. This is a two-wire half-duplex multipoint series connection where two lines are required in addition to a ground wire (Kim, 2014).

Finally, two lines are utilized for a power supply terminal. The DC12-24[V] and AC24[V] terminals are commonly utilized for camera power supplies. Therefore, an input and output terminal with a minimum of ten lines are required between the CCTV cameras and lifting system.

C. *Image Storage Device*

1. DVR

Analog images from early CCTV cameras were stored using a videocassette recorder (VCR), which utilizes the magnetic tape method called the vertical helical scan (VHS). The VCR was replaced by the digital video recorder (DVR) due to reasons such as low resolution, loss of images due to the deterioration of the magnetic tapes, and inconvenience in searching for images. The image processing board of the DVR, which is an A/D conversion unit, converts analog image data from the CCTV camera into digital data as shown in Figure 4.

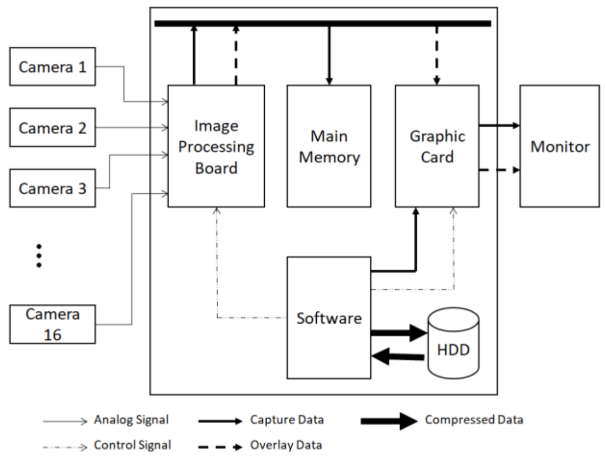


Figure 4. Block diagram of the DVR system

The DVR is a system that compresses the converted images using an encoding algorithm and stores them on a digital image storage device such as hard disk (HDD) or digital video disk (DVD). Images saved on a device such as the HDD can be stored semi-permanently, and the recorded images can be searched with the desired date and time or with specific events. In addition, the recorded images can be searched or viewed in real time from a remote location (EOM, 2017; Choi, 2012). The DVR system is largely classified into personal computer (PC) based type, stand-alone type, and Internet protocol (IP) based or network-based type. For the PC-based DVR, the Windows operating system (OS) is used from a convenience perspective, and the Linux OS is used from an economic perspective. Because high-end CPUs are used for the PC-based DVR, further development is easy. Hence, the PC-based DVR is primarily used in the system integration (SI) field. The stand-alone DVR has advantages such as excellent stability and low price. However, it has a disadvantage in that it is difficult to implement new features through additional development. Lastly, the IP-based or network-based DVR is similar to the stand-alone DVR in terms of the functions it supports. In addition, it also has the capability of sending the image data through a network without using a storage device (Choi, 2012).

2. NVR

The network video recorder (NVR) is a system that receives images from cameras or video servers on the network and stores the images. The DVR has a drawback in that it needs to be connected to all the cameras via dedicated lines for image and control data, but the NVR can easily connect to the cameras using a public network. The DVR records analog images provided by the analog surveillance camera. On the other hand, the NVR, with its enhanced network functions, receives real-time transport protocol—a protocol for the transmission of media packets—(RTP) packets from the IP camera, and then encodes the packets using the H.264 standard and records the video images as shown in Figure 5 (Choi,2012; Kim,2014).

The NVR performs recording and playback simultaneously, and the video images are recorded on a single device. Therefore, multiple authorized operators who are scattered throughout the network can view the video images remotely at the same time. The authorized users operate independently, so they do not affect each other. In addition, it is easy to expand the NVR system. Even if the system has many NVRs, the addition of one more NVR unit can be accomplished by simply connecting it to the network (Yong *et al.*, 2010).

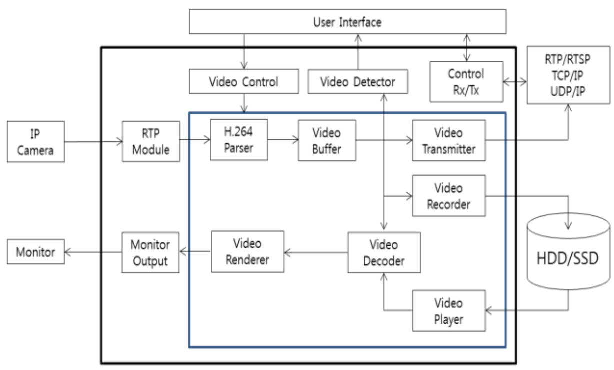


Figure 5. Block diagram of the NVR

The image compression performance limits the number of cameras connected to the DVR. On the other hand, the number of cameras connected to the NVR is limited by the performance of the network that receives the images, the data storage performance for saving the received imaged data in real time, the performance of encoding the received image data and displaying it on the monitor, and the resolution of the received image as shown in Table 2. The NVR performs recording and playback simultaneously, and the video images recorded on a single device can be viewed remotely by multiple authorized operators from all over the network at the same time. The authorized users operate independently, so they do not affect each other.

The NVR's biggest competitive edge is its compatibility with IP cameras from different manufacturers. To ensure this compatibility, the open network video interface forum (ONVIF) protocol, an international standard protocol, is applied.

Table 2. Differences between the DVR and the NVR

	DVR	NVR
Camera type	Analog camera	IP camera
Multi-stream	One cable required per camera	Multiple cameras connected to a single LAN
Image transmission medium	Coaxial cable	LAN/WAN
Maximum number of channels	Maximum 16	Unlimited
Scalability	Limited	Superb
Installation space	Large installation space	Small installation space
Maintenance	Difficult	Easy

D. Image Transmission Protocol

1. ONVIF

Systems that transmit images from current CCTV cameras primarily use the ONVIF protocol. The ONVIF protocol provides a global, open standard for the interface to ensure effective interoperability of the IP-based physical security products. The ONVIF is a global and open industry forum that was founded in 2008 to promote the use of the ONVIF protocol (Baek *et al.*, 2012). The ONVIF protocol has the advantage that it can be used freely in an HTTP-based proxy environment or a firewall environment. Internally, the ONVIF protocol is composed mainly of two protocols as shown in Figure 6. One of these protocols is the UDP-based RTP/RTSP protocol, used for sending and receiving images, voices, and events. The other one is the web services description language (WSDL) and simple object access protocol (SOAP) used for control, settings, and inquiry.

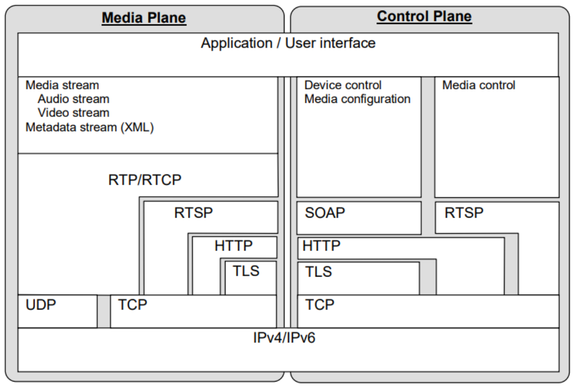


Figure 6. ONVIF layer structure

The ONVIF protocol is the open interface standard for video surveillance and other physical security aspects of IP-based products. The ONVIF protocol consists of the network video transmitter (NVT), network video display (NVD), network video storage (NVS), network video analytics (NVA), and network video client (NVC) services (Baek *et al.*, 2012). Each service needs to be implemented as a web-based service, and the service should be provided to a remote location even if the client and the server have different environments. The main services of the ONVIF protocol are shown in Table 3. And Embedded DVR using SoC (System on Chip) based low power one chip is also used in small scale system (Shah *et al.*, 2017).

Data is expressed in an XML-based format for web services, and the ONVIF standard uses the HTTP protocol to communicate. SOAP, which is an XML-based ultra-light protocol developed for sending and receiving data, is used for communications between the server and the client. In addition, the server uses WSDL to provide service descriptions for the services it supports.

Table 3. Main Services of the ONVIF Protocol

Service	Description
Discovery	Describes how devices are discovered in local and remote networks
IP Configuration	Defines the ONVIF network IP configuration requirements
Device Management	Defines the configuration of basics like network and security related settings.
Imaging Configuration	Services for exposure time, gain and white balance parameters among others
Event Handing	Defines how to subscribe to and receive notifications (events) from a device
Device IO	Currently relay ports and Video/Audio Inputs/Outputs are handled
Media Configuration	Media configuration entity such as video source, encoder, audio source, PTZ, and analytics
PTZ Control	Function that diminishes or crops an image to adjust the image position and ratio
Video Analytics	Algorithms or programs used to analyze video data and to generate data describing object location and behavior.

Moreover, the universal description, discovery and integration (UDDI) is used to search for these services. The UDDI requires a service broker, which saves the list of services; however, it is not suitable for the ONVIF protocol because devices that are on the same network, such as IP cameras, need to be searchable without the help of a service broker. Hence, the ONVIF protocol does not use the UDDI. Instead, it uses the device discovery function, which can search devices on the same network (Shah *et al.*, 2017). The device search function of the ONVIF protocol is related to the device management service, and it is the extended version of WS-Discovery, which is the standard for searching devices installed on the same network. Furthermore, WS-Discovery was extended to search devices on a different network as well as on the same network, and the SOAP-over-UDP technology is used to search the devices (John, 2005; OASIS Standard, 2009).

2. RTSP

The RTSP is a communications protocol developed by IETF in 1998, and is defined in the RFC 2326. The RTSP is used in streaming systems, and is used to control the server remotely. The commands for this protocol are similar to the VCR function names such as "PLAY" and "PAUSE," and the protocol accesses the server based on the time information. The RTSP does not actually transmit streaming data. Most of the RTSP servers use the RTP protocol to send the actual audio and video data to the transport layer (Hwang & Park, 2016).

The RTSP protocol is similar to the HTTP protocol in terms of syntax and functions, but the HTTP protocol is stateless while the RTSP protocol is stateful. A random session ID is used whenever a session is tracked, and this method requires a permanent TCP connection.

The RTSP messages are sent from the client to the server. If an error occurs in the server, the server sends the client the response code for the error. Basic RTSP request messages are sent using a procedure similar to the one shown in Figure 7, and the default port number is 554 (Hwang & Park, 2016).

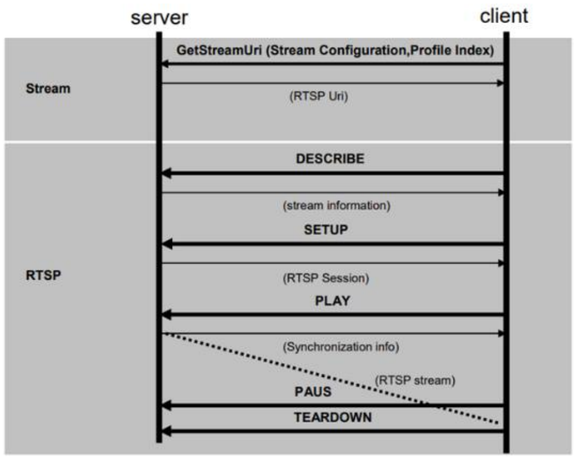


Figure 7. Stream control

III. MAIN SYSTEM BODY

A. *Interface design*

1. Connection terminal

Electric coupling between the CCTV cameras and lifting system is facilitated by pogo pins in the upper and lower sockets, as shown in Figure 8.

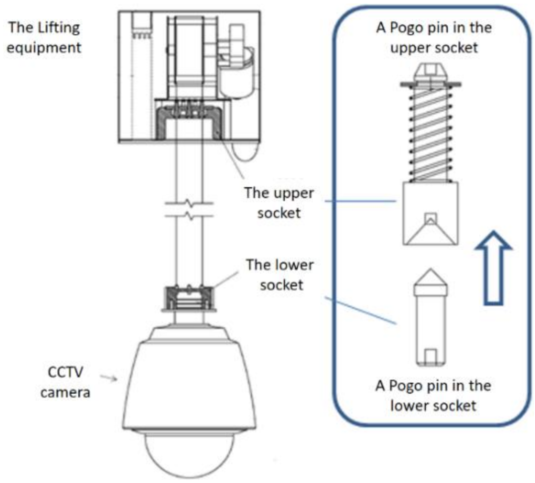


Figure 8. Coupling of upper and lower sockets via pogo pins

A Pogo pin is a part used in electronics to establish a connection between two circuit boards. The pogo pin usually takes the form of a slender cylindrical receptacle containing a sharp, spring-loaded pin. Pressed between two electronic circuits, the sharp points at each end of the pogo pin make secure contacts with the two circuits and thereby connect them together.

The impact of any mechanical contact on the pogo pins is not directly applied to the rear component, but is instead absorbed by the inner springs. The electric conductivity of the brass pogo pins is 24.6–34.5% based on the International Annealed Copper Standard. Their surfaces are coated with metal with a conductivity of 71.8% to improve their overall conductivity and prevent corrosion. Therefore, when the electric connection between terminals is unstable, heat generation caused by contact resistance, deformation of the contact areas, and oxidation are prevented.

Additionally, to study the changes in the contact resistance of the pogo pins caused by repeated contact and separation of sockets, lifecycle evaluation of the pins in the upper and lower sockets was performed, as shown in Figure 9. The load applied to the upper pin was 250 g on average. Over 500,000 loading cycles, it was confirmed that an average contact resistance of 5.498 mΩ was consistently maintained.

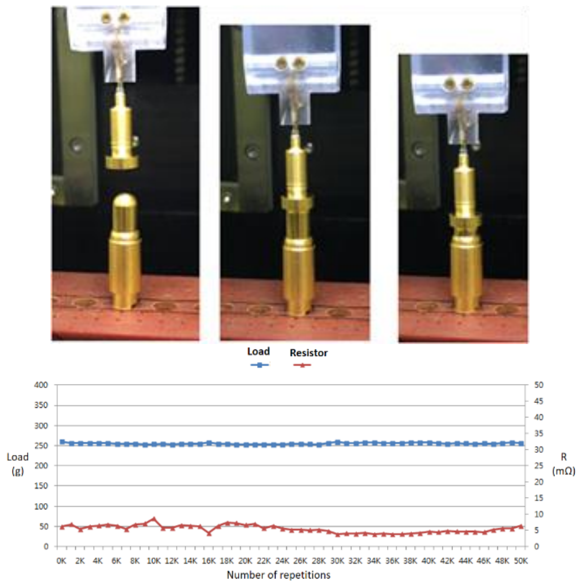
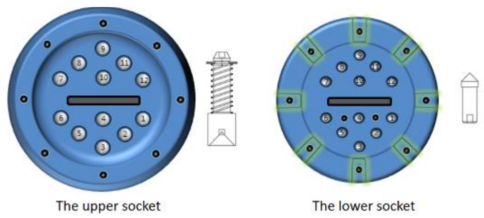


Figure 9. Pogo pin lift evaluation

(a) Evaluation method (b) Evaluation results

2) The upper and lower sockets

The lower socket, to which CCTV cameras are connected, is also connected to the upper socket of the lifting system. Each socket consists of 12 male and female terminals with pogo pins, as shown in Figure 10. Ten pins are utilized for the essential interface terminals of CCTV cameras and two pins are utilized for detecting the connectivity of the upper socket.



Name	Power		Video		Control		Contact		Transmit		Receive	
No.	1(+)	2(-)	3(TX+)	4(TX-)	5(RX+)	RX(-)	7	8	9(TX+)	10(TX-)	11(RX(+)	12(RX-)
Cable	AWG18		RG179/RG59(75Ω)		AWG20		AWG20		CAT5-E/6			
Color												
					floodlights				floodlights			
					AWG18				AWG18			

Figure 10. Socket pin array

The intervals between pins, their layout, and the wires utilized for connection were selected and implemented considering the voltage, current, frequency, and other elements of the pins to ensure that there would be no mutual interference. To ensure that the upper and lower sockets are correctly inserted, the belt was designed to pass through the belt holes in the sockets. Additionally, insertion guides were designed for the sockets to ensure that they are coupled in the correct orientation. The guides for the upper socket are wide at the bottom and grow narrower toward the top, whereas the guides for the lower socket are narrow at the top and grow wider toward the bottom. Furthermore, external guides were installed utilizing wires to minimize the shaking of cameras during lifting.

With the external guides installed as shown in Figure 11, lifting of cameras is possible with a maximum wind velocity of 10.7 m/s. It was also confirmed that the system operates as intended with a wind velocity of approximately 5.4 m/s without external guides

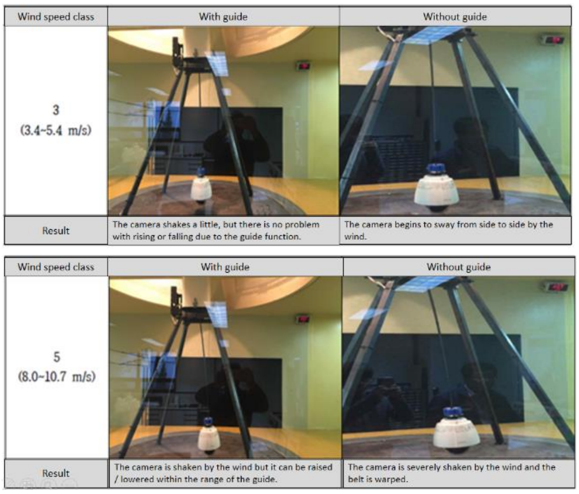


Figure 11. Wind tunnel tests

B. Motor driver design

1. Actuator

The weight of a general dome-shaped CCTV camera is approximately 5 kg or less. However, to stably lift this type of camera, a motor that can lift the maximum lifting weight or more must be selected. As shown in Figure 12, the electric power of the motor is transmitted through a reduction gear. Therefore, a power efficiency of 93–96% was applied to a spur gear and a power efficiency of 85–90% was applied to a worm gear. Because there is power loss during camera lifting as a result of winding the belt by utilizing the power transmitted through the gears, a coefficient of transmission of 20% was applied to correct this power loss.

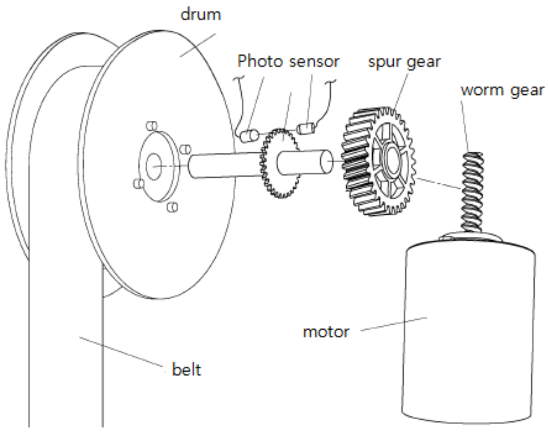


Figure 12. Illustrated actuator of the lifting system

2. Driver

Generally, transistors, FETs, relays, and motor driver ICs are used to drive a motor by an MCU. The rated voltage of the motor applied in this paper is DC24V. And when the motor lifts a 10kg camera, it needs about 2A current, and at the time of starting, the motor flows 5 ~ 6A current. The motor requires about 2A current to pull up the 10kg camera, and at the start of driving, 5 ~ 6A of current flows in the motor. When a semiconductor component such as a transistor or a FET is used as a motor driver, a heating problem may occur due to a continuous operation current. In this paper, MCU circuit is protected from surges and electrical noises generated in various industrial fields, and a durable electromagnetic relay is applied as a motor driver.

C. Sensor design

1. Sensing camera locations

To take down CCTV cameras from high places and keep them stationary at a designated location utilizing an automatic system, there must be a sensor that can detect the current locations of cameras. Such detection functionality can prevent the damage or contamination of cameras that may occur when cameras fall to the ground as a result of the carelessness of operators or mechanical malfunctions. Therefore, in the proposed system, an encoder and photo interrupter were installed along the axis of the belt-winding drum utilized for camera lifting.

The photo interrupter was designed to output 50 pulses with each rotation of the drum. The number of pulses increases when the main control unit (MCU) issues a command to lower a camera and decreases when the MCU issues a command to lift a camera. In this manner, the proposed system can detect the current locations of cameras. When cameras are connected to the upper socket of the lifting system during the lifting command, connectivity is detected by a limit switch connected to two of the twelve terminals within the socket. This allows the system to halt the motor to prevent damage to the socket or terminals, and to prevent overheating of the motor or driver. Additionally, information regarding camera locations is transferred to the MCU to determine the next action.

2. Detection of lifting system status

When the proposed lifting system operates normally, there is the current of 400 mA flowing through the motor during the lowering operation and a maximum current of 2.5 A during the lifting operation with a load of 10 kg. However, when the lower socket installed on a camera is coupled abnormally with the upper socket or the belt does not function because of an obstruction, it leads to excess current in the motor. In this case, the power to the lifting system is shut off and the system is defaulted. To prevent this issue, there must be a function to shut down the motor when there is any excess current for a certain period of time. To measure the current flowing through the motor, a shunt resistor was installed in the motor in a serial configuration, as shown in Figure 13.

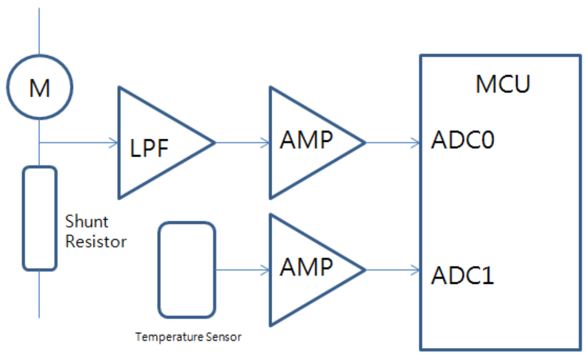


Figure 13. Actuator schematic for the lifting system

The current in the motor is indicated by the voltage of the shunt resistor, which is measured utilizing the analog-to-digital converter (ADC) of the MCU. At this stage, a fast recovery diode and active low-pass filter (LPF) are utilized to protect the MCU and ADC, and eliminate high-frequency noise caused by sudden electromotive forces There is a temperature sensor installed in the lifting system to regularly measure the interior temperature of the device. This is because there is a potential for malfunction when the temperature of the system rises above its optimal operating temperature, which can occur when the system is exposed to direct sunlight. The system operates ventilation fans to reduce the interior temperature when the measured temperature is higher than the optimal operating temperature.

D. Input unit design

1. Input hardware

The lifting system is controlled by a wired control switch, radio-frequency (RF) wireless remote controller, and smartphone app via Bluetooth.

First, the wired control switch is separate from the lifting system and is installed at a height of approximately 1.5 m from the ground for user convenience. In this case, electric noise may enter from the outside world through the wiring of the switch. To prevent this issue, for input through the wired control switch, an LPF and varistor are attached to protect the MCU and prevent malfunctions.

Second, the RF wireless remote controller utilizes the frequency band of 700 MHz to control the lifting system within a radius of 10 m. To prevent interference from frequencies generated by other devices within the same frequency band, the remote controller is designed to transmit 12-bit data with 8-bit identification codes and 4-bit operation codes.

Finally, a control command can be transmitted via Bluetooth communication utilizing a smartphone app. The smart phone app is compatible with Android OS devices that support Bluetooth functionality. The Bluetooth communication of the lifting system is designed to input and output through the universal asynchronous receiver-transmitter port of the MCU utilizing a serial conversion module for Bluetooth.

2. Input firmware

An environment where the lifting system is installed may be exposed to various forms of electrical or frequency noises. Because the lifting system receives commands through the wired switch, wireless remote controller, and smartphone app, a hardware filter circuit was installed to present interference from external noise and a firmware algorithm was developed to filter noise. To eliminate the impact of noise on inputs from the wired control switch and wireless remote controller, the firmware algorithm implemented in the lifting system only responds to the sleep mode and continuous "On" status of the switch, as shown in Figure 14.

When the system is inactive for a certain period of time, it automatically activates sleep mode. In sleep mode, the system ignores any motor control commands. This prevents malfunctions of the system because the system does not respond to external noise while sleeping. To end sleep mode and reactivate the system, a designated code must be maintained for three seconds or longer, or any other control command must be maintained for two seconds or longer. This eliminates the impact of intermittent external noise.

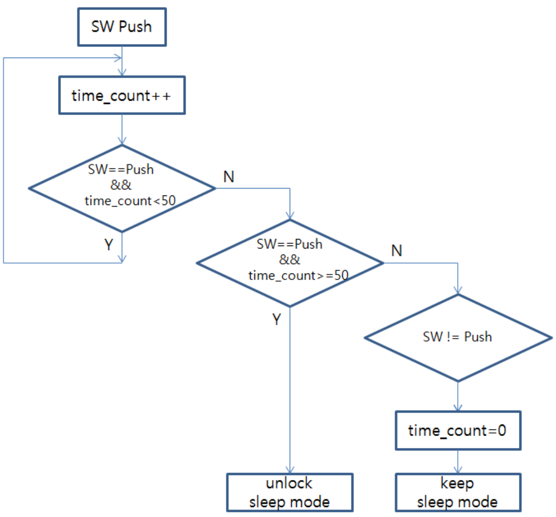


Figure 14. Sleep mode

IV. CONCLUSION

CCTV cameras are widely used for crime prevention and other security applications in daily life. They are also installed on general roads, highways, tunnels, etc. to monitor traffic status, as well as at core infrastructure facilities, such as power plants, military bases, and dams, for surveillance purposes. CCTV cameras in such places are typically installed at high places, introducing a high risk of falling during maintenance work, as well as other issues, such as long maintenance times and increased costs.

The automatic lifting system designed in this study is utilized for lifting or lowering CCTV cameras installed at high places to conduct safe and fast maintenance work. Both wired and wireless control systems were incorporated for user convenience when lowering CCTV cameras from high places and system reliability was enhanced through the application of filters and firmware to combat external noise. Furthermore, the proposed system provides enhanced safety through a dual-sensor system that prevents damage from excess current during motor operation. Equipment stability is also enhanced by location sensors that prevent collisions between cameras and the lifting system as a result of strong winds or other physical impacts.

Figure 15. Field application of the proposed system

As shown in Figure 15, the proposed system can be effectively utilized to facilitate safe and rapid maintenance of CCTV cameras installed at various locations, such as dams, plants, substations, and highways.

Table 4 compares CCTV camera maintenance methods, including the automatic lifting system proposed in this paper, based on data from 167 units of our automatic lifting system that were deployed by the Korea Expressway Corporation, Korea Electric Power Corporation, Korea

Water Resources Corporation, and Daejeon Metropolitan City for approximately 13 months. The data were obtained from CCTV managers, maintenance agencies, and operators from each institution. Each item in the table indicates an average value.

Table 4.Comparison of CCTV camera maintenance methods

	Traditional methods	Automatic lifting system	Improv -ement
Time for preparation (minutes)	43	5	760%
Time for maintenanc e (minutes)	7	6	17%
Number of operators	2.3	1.4	64%
Cost (won)	78,000	32,000	144%
Safety (5-scale)	2.8	4.9	113%

In conclusion, compared to traditional maintenance methods, the proposed automatic lifting system significantly reduced the preparation time required for CCTV camera maintenance at high places. A significant reduction in maintenance cost was also confirmed. Additionally, field operators provided positive feedback regarding safe on-ground maintenance work based on the automatic lifting system. Based on these results, we confirmed that the proposed automatic lifting system is superior in terms of speed, economy, and safety for conducting CCTV camera maintenance work compared to traditional methods.

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