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UWB/WiFi 모듈 기반의 내시경 카메라용 무선전송 설계☆

Design of UWB/WiFi Module based Wireless Transmission for Endoscopic Camera

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요 약

본 논문에서는 초광각 무선 내시경을 제안하고 구현하였다. 내시경은 초광각 카메라 모듈과 무선전송 모듈로 구성된다. 162도의 초광광 렌즈와 이미지 센서 및 카메라 프로세서가 3x3x9 cm3 크기의 케이스에 함께 패키지 된다. 무선전송 모듈로 UWB 기반 및 WiFi 기반의 플랫폼을 각각 구현한다. UWB 기반 모듈은 의 고화질 영상을 MJPEG로 압축하여, 2048x1536 (QXGA)의 해상도에서 15 fps의 속도로 영상을 전송하며, 최대 데이터 전송속도는 41.2 Mbps에 달한다. 구현된 내시경은 의료용 내시경의 화각과 해상도 수준을 가지며, 상용 고성능 WiFi 내시경과 비교할 때 ~3X의 화각과 16X의 해상도를 갖는다. WiFi 기반의 모듈은 640x480 (VGA)의 해상도에서 30 fps의 속도로 영상을 스마트 기기로 스트리밍 하며, 최대 1.5 Mbps의 데이터 전송속도를 보여준다. 구현된 모듈은 저가격의 의료용 무선 전자 내시경의 구현 가능성을 보여주며, U-헬스케어, 응급처치, 가정의료, 원격진료 등에 효과적으로 활용될 수 있을 것으로 기대된다.

☞ 주제어 : 초광각, 렌즈, 화각, 해상도, 카메라, UWB, WiFi, 내시경, MJPEG, 전송속도.

ABSTRACT

Ultra-wide-angle wireless endoscopes are demonstrated in this paper. The endoscope is composed of an ultra-wide-angle camera module and wireless transmission module. A lens unit with the ultra-wide FOV of 162 degrees is designed and manufactured. The lens , image sensor, and camera processor unit are packaged together in a 3x3x9-cm3 case. The wireless transmission modules are implemented based on UWB- and WiFi-based platform, respectively. The UWB-based module can transmit HD video to a computer in resolution of 2048x1536 (QXGA) and the frame rate of 15 fps in MJPEG compression mode. The maximum data transfer rate reaches 41.2 Mbps. The FOV and the resolution of the endoscope is comparable to a medical-grade endoscope. The FOV and resolution is ~3X and 16X higher than that of a commercial high-performance WiFi endoscope, respectively. The WiFi-based module streams out video to a smart device with th maximum date transfer rate of 1.5 Mbps at the resolution of 640x480 (VGA) and the frame rate of 30 fps in MJPEG compression mode. The implemented components show the feasibility of cheap medical-grade wireless electronic endoscopes, which can be effectively used in u-healthcare, emergency treatment, home-healthcare, remote diagnosis, etc.

☞ keyword : Ultra-wide angle, lens, FOV, resolution, camera, UWB, WiFi, endoscope, MJPEG, transmission speed.

1. Introduction

Traditional optical endoscopes has a complicated structure due to relay lens and optical fibers to transmit images and light, respectively [1]. This degrades the quality of images and increases the cost of endoscopes. With the development of CCD (Charge Coupled Device) image sensor, images could be transmitted electronically. However optical fibers has been widely employed to transmit light. Recently all-electronic digital endoscopes have been developed with the advances of CMOS image sensors and LED (Light Emitting Devices) technology [2]. The electronic endoscopes can be implemented with lower costs, yet have higher performance and reliability. Recently some wireless endoscopes becomes commercially available for industrial applications [3]. The FOV (field of view) of a high-performance product provides the FOV (field

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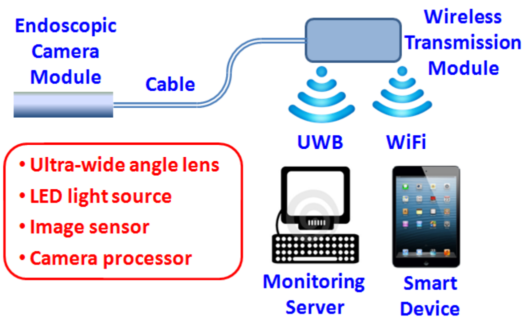
of view) smaller than 60 degrees and VGA resolution (640x480) [4]. The performance is not enough for medical applications considering that a popular medical endoscope has the 140-degree FOV and HD-level resolution [5].

This paper demonstrates a medical-grade wireless endoscope with an ultra-wide FOV and HD resolution. The schematic of the proposed ultra-wide-angle wireless endoscopic platform is shown in Figure 1. The endoscope is composed of the camera module, the wireless transmission module, and the communication cable. An ultra-wide-angle lens unit is designed and manufactured. An endoscopic camera module also includes LED light sources, an image sensor, a camera processor. The performance of the UWB module is analyzed while transmitting video to a monitoring server (computer). A WiFi wireless transmission module is also implemented to make the camera module a network device with an independent IP. The video from the WiFi module is streamed to be displayed in a smart device.

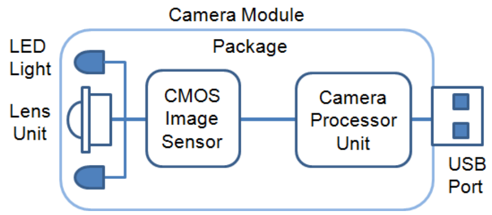


(Figure 1) Schematic of the proposed ultra-wide-angle wireless endoscopic platform.

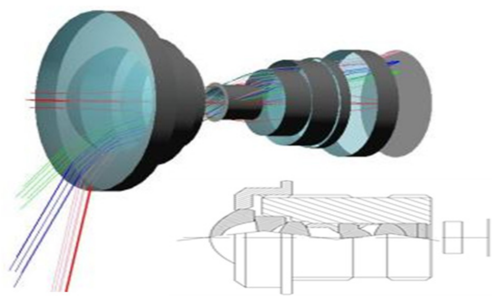
2. Design of Endoscopic Camera Module

Figure 2 shows the schematic diagram of the endoscopic camera module. The module includes a ultra-wide-angle lens unit, CMOS image sensor, camera processor unit, and LED lights. All components are packaged in a cylindrical case. The camera module is connected to the following wireless transmission module using the USB interface.

An ultra wide angle lens is designed and manufactured [6-8]. The lens is designed using various techniques like Raytracing, MTF (Modulation Transfer Function), Through Focus MTF, Field Curves, etc [9-10]. Six lenses are employed in the lens module. Three of them are made of plastic, and the rest are made of glass. Only one of the lenses has an aspheric shape to reduce costs in design and manufacturing. The designed FOV and F-number of the lens is 162 degrees and 2.5, respectively. Figure 3 shows 3-D modeling of the ultra-wide-angle lens for the proposed wireless endoscope. Important parameters of the designed lens including a focal length and TV distortion are summarized in Table 1. Figure 4(a) shows front-side and back-side of the manufactured ultra-wide-angle lens unit.



(Figure 2) Schematic diagram of the endoscopic camera module.



(Figure 3) 3-D modeling of the ultra-wide-angle lens for the proposed wireless endoscope.

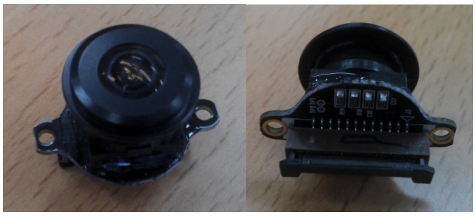
(Table 1) Design parameters of the ultra-wide-angle lens.

Lens parameter	Design value
Field of View (FOV)	162 degrees
F-number	2.5
Focal Length	1.5 mm
TV Distortion	25%
Iris	Fixed

A commercial CMOS image sensor, OmniVision OV3640, is employed for the camera [11]. The OV3640 is a high-performance 3.1 Megapixel (2048x1536) CMOS camera chip in a 1/4-inch optical format. The OV3640 image array operates at up to 15 frames per second (fps) in the resolution (QXGA). The sensor also contains an integrated compression engine simplifying bandwidth limited interface.

The image sensor is mounted on a small PC (Printed Circuit) board and enclosed by a plastic lens base. A circular IR-cut filter is placed on the rectangular image sensor to prevent colour distortion of images as the human eye sees. The lens module rotationally couples with lens base. An assembled camera module including the lens module and the image sensor is shown in Figure 4(b). A 24-pin FPC (Flat Printed Cable) connector is employed to connect the camera unit and the following camera processor module.

(a)



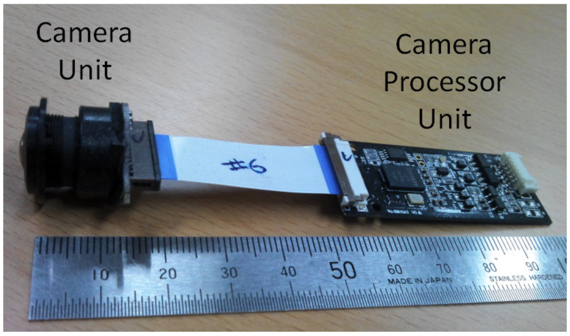
(b)

(Figure 4) (a) Manufactured ultra-wide-angle lens unit. (b) Assembled camera unit with 24-pin FPC connector.

The camera processor unit provides a system interface and the processing capability to connect raw image sensor to a following device. The developed camera unit is connected to a commercial camera processor (OmniVision OV538) to enables high-speed transfer of camera image data [12]. The OV538 is a low cost, enhanced single-chip processor for USB 2.0 PC camera applications supporting up to 2-mega pixel sensors.

A PC board is designed and manufactured to include the OV538, regulators, a crystal oscillator, a memory, passive devices, etc. The regulators generate multiple supply voltage levels for the image sensor. Figure 5 shows the photograph of the manufactured camera processor module. The size of the board is 70x20 mm^2. The camera unit is connected to the camera processor unit using A 24-pin FPC (Flat Printed Cable) as shown in Figure 5.

The camera module is packaged inside a cylindrical Aluminum case (Figure 6). The camera module can be directly connected to a wireless transmission module without a USB cable. The size of the packaged camera module is 3x3x9 cm^3. Two white LED are employed to implement the light source for the endoscope. Each LED draws 10 mA from the 5-V DC supply lines of the USB interface.



(Figure 5) Camera module with the camera unit and camera processor unit.

(Figure 6) Packaged camera module inside a cylindrical Aluminum case.

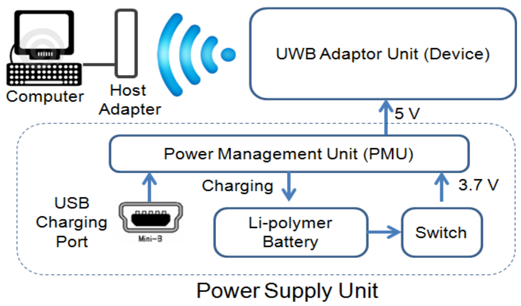
3. Design of UWB-based Wireless Transmission Module

3.1 Design and implementation

Ultra-Wideband (UWB) is a communications technology that employs a wide bandwidth (typically defined as greater than 20% of the centre frequency or 500 MHz) [13-14]. UWB communications are characterized by ultra-low power, high speed, and short range. UWB radios operate at such tiny transmit power that they do not cause interference with electronic devices or other types of radios [15].

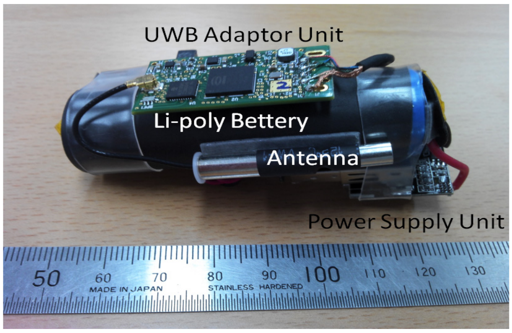
The wireless transmission of huge high resolution video data from a camera in real-time is challenging. The high-speed WUSB (Wireless USB) technology based on UWB should a good solution. Since UWB technology has no interference with Wi-Fi or Bluetooth, the proposed camera can sustain its performance even in the environment overcrowded by various wireless devices [16].

A commercial wireless adaptor module (Alereon AL5616) is used to implement the UWB transmission module [17]. The module includes two main chips: RF transceiver chip (AL5100) and baseband/MAC chip (AL5301) [18]. AL5616 is a precertified UWB radio card that can be used for both host side and device side applications. The UWB module employs multiband orthogonal frequency division multiplexing (MB-OFDM).



(Figure 7) Schematic diagram of UWB transmission module for the ultra-wide-angle wireless endoscope.

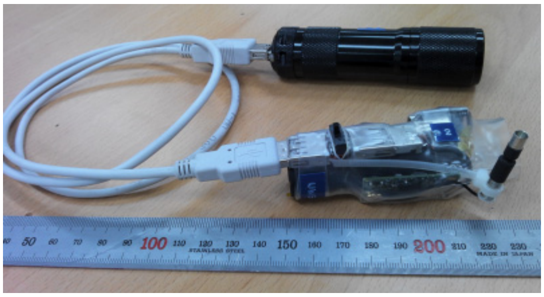
A Li-polymer battery, power management unit (PMU), switch, and UWB module are packaged to implement a stand-alone communication module for the endoscopy system. The PMU mainly boosts the output voltage of the battery (3.7 V) to 5 V to drive the UWB module using the USB interface [19]. The other function of the PMU is to charge the battery from a 5-V voltage source. The assembled UWB module is shown in Figure 8. The module size is 3.0x3.5x7 cm^3.



(Figure 8) Photograph of UWB-based transmission module for the wireless endoscope.

3.2 Measurement results

The performances of the camera are evaluated in an indoor environment. The resolution, frame rate, and data transfer rate of real-time video are measured. The camera module is connected with the UWB transmission module using a USB cable as shown in Figure 9. The UWB module is packaged using a transparent shrink tube. An oral cavity is observed using the endoscope to evaluate its performance. The teeth and tongue in the relatively dark environment are clearly seen due to the LED lights.



(Figure 9) Photograph of UWB transmission module connected to the packaged camera module using a USB cable.

(Figure 10) Observation of an oral cavity using the UWB-based endoscope module.

A video with a higher resolution can be transmitted at a substantially lower data rate using a video compression technique. The image sensor of the proposed camera (OV3640) supports the MJPEG (Motion JPEG) mode. Each video frame or interlaced field of a digital video sequence is compressed separately as a JPEG image in the video compression format [20].

Table 2 summarizes the measured performance of the camera using MJPEG image compression at the distance of ~1 m. The camera can support up to QXGA resolutions (2048x1536). The maximum data transfer rate reaches 41.2 Mbps for the resolution of 15 fps. The data rate goes up with the resolution as expected. The resolution, frame rate, and data rate are measured using VLC (VideoLAN), a free and open source cross-platform multimedia player and framework [21]. The endoscope shows the performance comparable to a medical-grade one [5].

(Table 2) Measured performances of the camera in MJPEG compression mode.

Resolution	Frame rate	Data transfer rate
640x480	30 fps	6.2 - 14.3 Mbps
1024x768	30 fps	10.4 - 27.0 Mbps
2048x1536	15 fps	20.2 - 41.2 Mbps

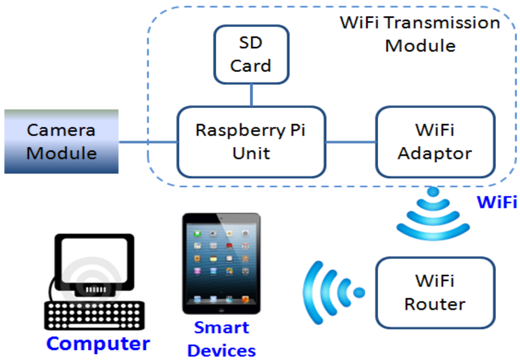
4. WiFi-based Wireless Transmission Module

4.1 Design and implementation

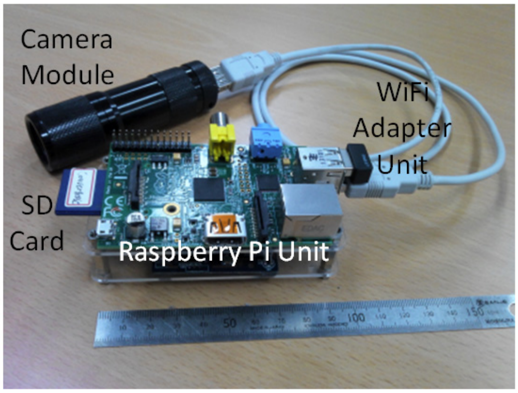
Due to the prevalence of WiFi networks and communication devices, a WiFi-based wireless endoscope can have higher flexibility than the UWB counterpart. For example, endoscopy images can be monitored in a remote place as far as WiFi network is available. Another advantage should be the connection with various smart devices with WiFi function as well as normal computers.

The WiFi transmission module is implemented using a credit card-sized single-board computer (Raspberry Pi: Model B) and WiFi modules (adaptor and router) [22]. The transmission module make the camera module a network device with an IP address. Figure 11 shows the schematic diagram of the proposed WiFi-based endoscope. The operating system, Raspbian, is installed in the SD card (32GB). The video data from the camera are processed by a library installed in the computer. Then the processed data are streamed to the WiFi router and displayed in a smart devices or a computers with WiFi function. Multiple devices can access the video simultaneously using the streaming technique.

Figure 12 shows the photograph of the implemented WiFi-based endoscope. The camera module is connected to the transmission module using a USB cable. “ipTIME mini” and “ipTIME N100 mini” is used for the WiFi adaptor and router, respectively [23].



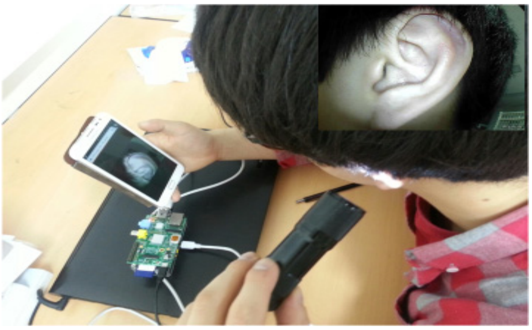
(Figure 11) Schematic diagram of WiFi-based wireless endoscope.



(Figure 12) Photograph of WiFi transmission module connected with the endoscopic camera module.

4.2 Measurement results

An ear is observed to evaluate the performance of the WiFi-based endoscope. The transmitted video images are displayed in a smart phone. Figure 13 shows a clear image of the ear transmitted by the WiFi-based module. The maximum date transfer rate supported by the module is estimated to be 1.5 Mbps at the resolution of 640x480 (VGA) and the frame rate of 30 fps in MJPEG compression mode. The performance is measured using VLC. The UWB-based transmission module should provide much better video quality since the resolution and the data transfer rate is 16X and ~30X higher than that of WiFi one, respectively. However, the WiFi-based endoscope has better flexibility and expandability due to easy connections with various devices through extensive WiFi networks.



(Figure 13) Observation of an ear using WiFi-based wireless endoscope.

5. Conclusion

A ultra-wide-angle wireless endoscopes is demonstrated in this paper. The lens module is designed to provide FOV of 162 degrees and F-number of 2.5. The lens unit is assembled with an image sensor. The camera unit and camera processor are packaged to a camera module. The wireless transmission is implemented using UWB or WiFi communication. Measurements show that the UWB-based transmission module can transmit HD video in the resolution of 2048x1536 (QXGA) and the frame rate of 15 fps with the maximum data transfer rate of 41.2 Mbps in MJPEG compression mode. The resolution is 16X higher than that of a commercial high-performance WiFi endoscope. The performance is comparable to a medical-grade endoscope. A WiFi-based transmission module is implemented using the Raspberry Pi and a WiFi adaptor. The maximum date transfer rate of 1.5 Mbps is achieved at the resolution of 640x480 (VGA) and the frame rate of 30 fps in MJPEG compression mode.

These results show the feasibility of cheap and convenient medical-grade wireless endoscopes, which can be extensively employed in u-healthcare, emergency treatment, home-healthcare, remote diagnosis, etc.

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