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ORIGINAL PAPER

Development of a digital infrared video camera system for recording and remote capturing

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Abstract A digital infrared video camera system was developed for recording and remote capturing. The components are described in detail. Based on 2 years of experience within a wild boar (*Sus scrofa*) project, the system gave proof of its practicability, reliability and efficiency.

Keywords Illuminator · Real-time data transmission · MOBOTIX

Introduction

The Research Institute for Forest Ecology and Forestry of Rhineland-Palatinate (FAWF) planned to purchase three video camera systems for different applications in the future. They should be able to operate separately.

For this reason the following requirements were defined:

- operation outdoor: in the wildlife research area which is located in the Palatinate Forest, southwestern Germany, with moderate Atlantic climate
- operation all over the year
- for day-and-night use
- own energy supply because there is no power connection available
- energy supply for at least 48 h, maintenance-free
- at least 12 h permanent recording
- very good image quality
- motion detector with sufficient sensitivity and adjustable event management
- easy mounting to be possible for one single person
- setup without attracting attention of animals (not to frighten away the target animals, to avoid damages caused by animals) and people (to avoid vandalism and theft)
- separately operating infrared illuminators to be flexible concerning the numbers per video camera system (different light conditions)
- observation and triggering of a trap in a distance of approximately 500 m
- easy and time-saving analysis of the recorded streams
- easy and time-saving data processing including backup and storage

Especially because of the last two needs, the FAWF looked for a digital solution.

There was no appropriate video camera system available on the market. There were only very few information accessible about the operation of digital camera systems in wildlife projects. Although digital video and photo techniques are becoming more common in the recent years, still no special guide to this kind of equipment and methods is available, and many small but very important technical details are often skipped in research papers (Reif and Tornberg 2006). Most of the wildlife ecologists dealing with self-triggered video cameras worked with conventional analogue systems or at least analogue components: Scheibe et al. (2007) used a video camera system for continuous surveillance of selected areas or spots in the field as a time-saving, reliable and durable tool for monitoring large wild animals. The scraping behaviors of a wild population of white-tailed deer were monitored by Alexy et al. (2001) and forest carnivores and fishers were detected by Aubry et al. (1997). Pfister et al. (1997, 1999) and Georgii et al. (2006) studied the use of

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wildlife passages at roads and railway lines by medium-sized and large animals with a very effective analogue system. Prey delivered to nestlings was detected by Currie et al. (1996) by filming the adults flying into the nest hole. Others observed the nests (Dearborn 1996; Delaney and Grubb 1998; Hughes and Shorrock 1998; Liebezeit and George 2003). Reif and Tornberg (2006) reviewed the most common surveillance techniques used in nest studies and described the digital video recording technique. A portable system for continuous monitoring of bird nests using digital video recorders was developed by Pierce and Pobprasert (2007).

Most part of the experience concerning digital video camera systems existed in the security sector with different conditions and needs. These systems are built for a supply voltage of 230 V and there is no or few vegetation influencing the infrared light. Yasuda and Kawakami (2002) developed a video streaming–monitoring system for remote wildlife: a USB PC camera was set up outdoor but was connected with a computer in a laboratory powered by electrical current. None of the mentioned systems meet all our requirements.

As a consequence, the FAWF was forced to develop an appropriate system by itself. The innovation did not contain the construction but the selection, composition and connection of the components. For that purpose, the FAWF worked together with the company uniserve GmbH (Meschede, Germany). This video camera system is presented in Fig. 1.

Video camera system

As a video camera, the network camera "M10D-Night" from MOBOTIX (Kaiserslautern, Germany) was chosen. The dimensions of the housing are 143×56×224 mm (width×depth×height); the weight is 850 g (including wall mount). Due to the stand-alone principle, the camera includes rain and sun protection, passive infrared motion detector, microphone, loudspeaker, memory and software. The microphone was helpful, for example, in capturing wild boars that are outside the picture frame because the sound showed their presence. Provided for pictures was 36 Mbyte of the 64 Mbyte internal memory. As an example, approximately 2,400 JPEG pictures with a resolution of 320×240 pixels can be stored as a photo trap. For long video streams, an external memory is necessary. This camera version has two lenses: a colour day and a black-and-white night lens. The fully digital colour CMOS image sensor with 1280×960 pixels has a backlight correction; the fully digital black-and-white CMOS image sensor with 1280×960 pixels, an eight-times-higher sensitivity than the colour sensor (day lens sensitivity (8 mm/2.0), 1 lux at 1/60 s, 0.05 lux at 1 s; IR/night lens sensitivity (8 mm/2.0), 0.2 lux at 1/60 s, 0.005 lux at 1 s). Depending on the lighting conditions, the camera switches automatically from day to night sensor. The frame/data rates for the MOBOTIX MxPEG video streaming format (50% JPEG) are

25 F/s	CIF	(320×240)	1.2 Mbps
12 F/s	VGA	(640×480)	1.3 Mbps
4 F/s	Mega	(1280×960)	1.2 Mbps

According to MOBOTIX, the camera features the highest operating temperature range in the market from −30°C to +60°C (certified according to IP 65; a MOBOTIX camera

Fig. 1 *Left*: weatherproof, isolated and lockable box of digital video camera system with open lid: at the *top* the battery, in the *middle* the voltage converter and at the *bottom* NAS. *Right*: digital video camera (at the *bottom*) with infrared illuminator (at the *top*) and twilight switch for the infrared illuminator (in the *middle*). The infrared illuminator is attached to a small board so that it can be adjusted easily. This board is fixed with strips to a tree trunk

is in action at the German Antarctic Receiving Station (GARS) in O`Higgins/Antarctic). Until now there have been no problems with the camera in the moderate climate of the Palatinate Forest (annual average air temperature (1988–2005), 9.7°C).

The comprehensive software offers a very wide range of settings. With various adjustments, the quality of image/stream can be optimised. Besides, the passive infrared motion detector events (e.g. recordings) can be started by using the video motion detection of two separate image sensors (for the day and the night lens). This feature evaluates changes in pixel brightness between two succeeding live images of the camera. One or more motion detection windows per lens can be created (Fig. 2) and the sensitivity defined. In order to avoid unwanted events triggered by moving vegetation in front of the lens or snowfall, a video motion reference window can be defined. If there are changes in pixel brightness both in the video motion window and the reference window simultaneously, the camera will not trigger an event. All distinct configurations can be stored. Thus, a quick readiness for use is possible.

Because of the lack of a screen, a laptop is used for aiding camera placement. If the camera is connected to the laptop, access is obtained by means of the IP address. Six light-emitting diodes on the front show the status of the camera. It is recommended to switch these light-emitting diodes off, so that animals are not disturbed or people are not attracted.

The camera is connected to a box by 20 m of cable (IP 67). Due to a connector at the outside lid (Fig. 2), the box need not to be opened which could be advantageous in case of precipitation. All other elements of the system are stored in this weatherproof, isolated and lockable box [inside dimensions, 510×360×270+80 mm (length×width×height+height of the lid] made of very solid plastic: voltage converter, switch, NAS (Network Attached Storage), battery and VDSL (Very High Speed Digital Subscriber Line) modem in case of the real-time data transmission option (see "Real-time data transmission"). Figure 3 shows the connections between the components. Two handles are helpful for transportation.

The system operates at 12 V. All components are built for this voltage except the camera (30 V). Therefore, a voltage converter is needed. We used a 12-V gel cell battery (80 A h, 259×168×208 mm (length×width×height), 23.3 kg, no memory effect, maintenance-free): it is small enough to fit into the box and sufficiently light to enable its assembly by just one person. The costs then (see "Costs") were acceptable and the capacity was sufficient for our objectives. Because of low power consumption, the battery supplies at least 52 h of continuous power with the VDSL modem switched on (see "Real-time data transmission") and about 100 h with the VDSL modem switched off. The battery is rechargeable overnight.

The NAS [80 Gbyte; connection speed, 10/100 Mbps; 220×132×60 mm (length×width×height)] serves as a hard disk for data storage. If a second NAS is available, the data need not to be downloaded to your laptop. In comparison with this time-consuming data transfer, the exchange of the NAS is very fast and the place can be left with a minimum of disturbances. Back at the office, the NAS can be connected to the computer or network to watch the streams. Thus, only the wanted streams can be downloaded from the NAS that enables approximately 140–680 h of recording (depending on the settings). For data processing, the mentioned video camera software or the software "MxPEG Viewer", which MOBOTIX offers for free, can be used. With this software, a time-saving analysis is possible. For example, a selection of all first pictures of the triggered events allows a fast assessing if the events were triggered by a wanted or unwanted event.

Infrared illuminator system

For night use, an infrared illuminator is necessary. The camera lens is optimised for wavelengths of 800–900 nm.

Fig. 2 *Left*: screen print of the black-and-white night lens of the digital video camera with motion detection windows (*rectangles* with *dotted lines*). These motion detection windows evaluate changes in pixel brightness between two succeeding live images. *Right*: weatherproof, isolated and lockable box of digital video camera system with two connectors at the lid: one for the digital video camera, the other for a real-time data transmission option

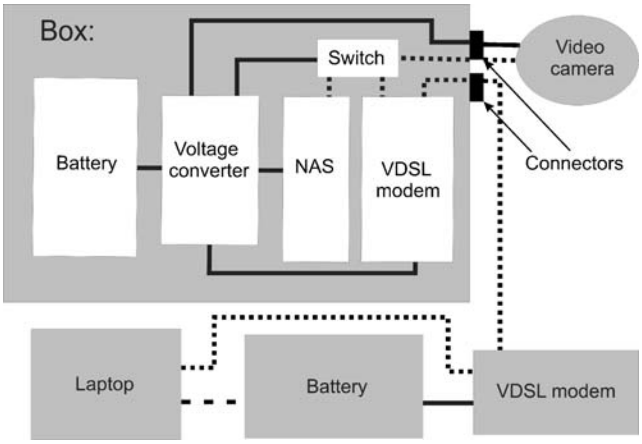

Fig. 3 Connections between the components of the video camera system with real-time data transmission: LAN cable (*dotted lines*), electrical cord necessary (*solid lines*) and electrical cord possible (*dashed line*)

After testing different types of illuminators, an infrared illuminator system with the “84/30–880” from uniserve GmbH was built (wavelength, 880 +/−20 nm; scene coverage, 35 m; lateral beam width, 30°; power consumption, 1 A; supply voltage, 12 V DC; temperature range, −30°C to +40°C; dimensions, 90×90 mm; weight, 1 kg) (Fig. 1). The round shape of the illuminator causes a slight circular overexposure in the middle of the scene coverage which can be eliminated by software settings. In order to reduce the energy consumption, a twilight switch [supply voltage, 12 V DC; relay contact, 3 A/25 V/DC; dimensions, 75×50×41 mm (length×width×height)] with a photoelectric cell detects the brightness and switches off the infrared illuminator by a threshold value of approximately 45 lx. The battery is the same as that for the video camera system. The box type is also identical but smaller [inside dimensions, 460×320×160+80 mm (length×width×height+height of the lid)]. The infrared illuminator is connected by 20 m of cable to the lid of the box. Besides the battery, the illuminator and the cable with the twilight switch fit into the box for transportation and storage. This infrared illuminator system runs for at least 48 h with one battery.

Mounting

A sturdy mounting is recommended. Otherwise, the movement of the camera could trigger an unwanted event because the video motion window detects an imaginary movement of the background. For the same reason, vegetation should be removed in front of the lenses.

Because of a ball joint wall mount, the camera can be mounted first and the precise adjustment can be carried out afterwards. The illuminator is attached to a small board so that it can be adjusted easily (Fig. 1). This board can be fixed with, for example, strips to a tree trunk.

In order to avoid attention of animals or people, the colours of the components should be dark or camouflaged. The boxes are black and can be dug into the ground. The illuminator housing is also black, while that of the camera is white. We did not observe an influence on species like wild boar (*Sus scrofa*), roe deer (*Capreolus capreolus*), wildcat (*Felis silvestris*), red fox (*Vulpes vuples*) or marten (*Martes* sp.). Painting of the camera housing will lapse the warranty given. Putting the camera in a nesting box could be an option. The cables are available in dark colours.

Real-time data transmission

Due to the requirements of the FAWF to be able to observe a wild boar trap and to trigger the trapdoor via video camera from a distance of several hundred metres without disturbing the animals, a real-time data transmission was necessary. Wireless local area network (LAN) was tested but was found to be unsuccessful. Therefore, the VDSL technology was used. Five hundred metres of cable was wound up on a cable reel with wheels to make the assembly and disassembly easier. For setting up the real-time data transmission, one side of the cable must be connected to the VDSL modem in the box of the video camera system (there is a connector at the lid), the other side to another VDSL modem which is linked to a laptop. This VDSL modem and the laptop can also be supplied with energy from a 12-V gel cell battery or connected to a strong car battery. After creating a softbutton with the help of the video camera software, the trap can be closed by pressing this softbutton on the screen of the laptop: a signal is sent to a relay which causes a movement of a pin. This movement activates a triggering system (Kieferle GmbH, Randegg, Germany) and the trapdoor held by a string is released and it falls down.

Costs

The costs of the components are listed below (up to 2005):

Video camera “M10D-Night”	1,405.37 €
NAS disk server	406.– €
Voltage converter	116.– €
Box	348.– €
Cable (IP 67)	60.32 €
Miscellaneous (e.g. switch, fuses, isolation, clips, deep discharge protection)	174.– €
Infrared illuminator system	560.28 €
Real-time data transmission	632.20 €
Battery	124.57 €
Charger	161.24 €

Conclusion

Until now, the FAWF has operated this digital infrared video camera system for 2 years within a wild boar project to record the behavior of this species and to capture wild boars in boxes or corrals from a distance. So far, the system has been working reliably. Only one problem with a connector occurred which could be solved. The image quality is excellent, and the video stream analysis and data processing is time saving. For our applications, the system was worth the money.

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