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A Real-Time VIDEO-STREAMING SYSTEM for Monitoring Demining

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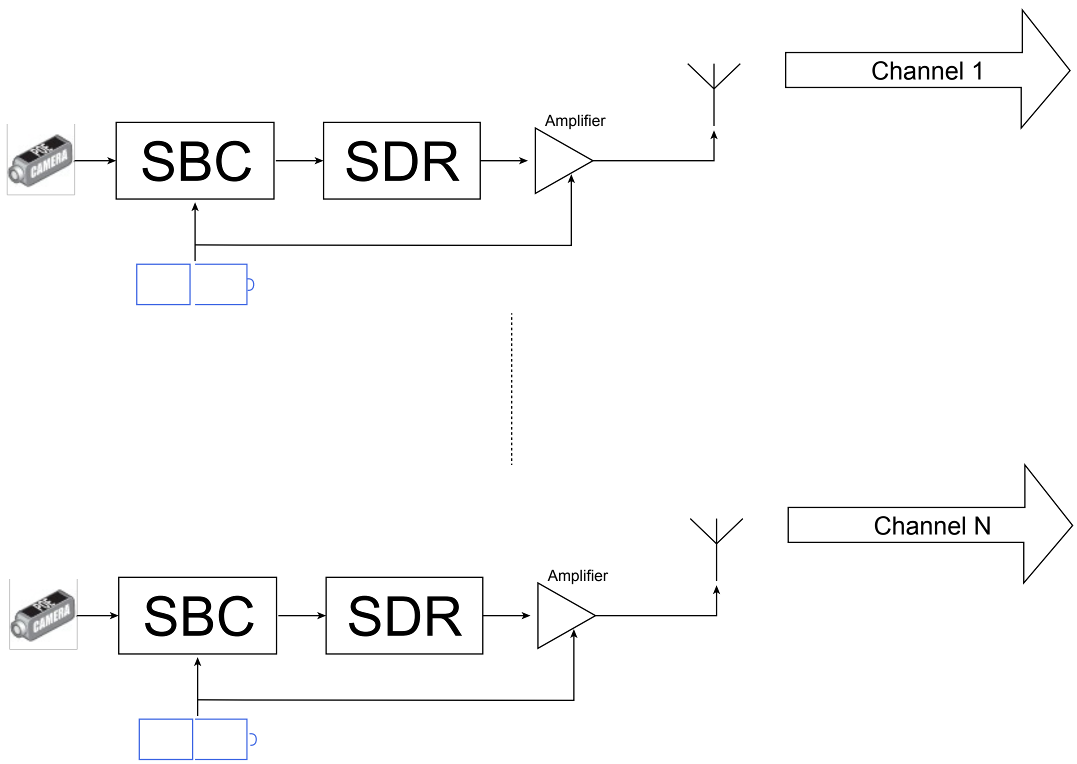

Figure 1. Diagram showing the components of the video-streaming subsystem. Each deminer using the system will be equipped with one of these subsystems.
All graphics courtesy of the authors.

The most deployed detection technology for landmine clearance is the metal detector (MD).[1] Other detection technologies exist, such as ground penetrating radar,[2] chemical sensors,[3] biological sensors,[4] and infrared imaging,[5] to name a few. However, despite their widespread use, MDs suffer from high false-alarm (FA) rates since they cannot differentiate between the metal components in a landmine and harmless metal clutter. Deminers using MDs usually rely on their personal experience to differentiate between the sounds emitted by the MD when scanning a landmine or an item of clutter. Usually, they continue to excavate on a large number of occasions and end up finding a harmless piece of metal. For each found landmine, it is estimated that a hundred to a thousand false positives are encountered.[6] The high FA rate substantially slows the demining process and increases costs. This delays the recovery of contaminated land and the resumption of everyday activities around the affected areas.

Despite the training and the protocols that are put into place to make the demining process safe, accidents do happen during clearance operations.[7] Preventing or at least minimizing the number of accidents is essential. When an accident happens, it is necessary to know exactly what happened and why it happened. This helps determine responsibility and prevent similar accidents in the future.

In this article, the authors present a real-time video transmission system—the Demining Monitoring System (DMS)—that can be used to closely monitor the activities of deminers during humanitarian landmine clearance. This system comprises a high-resolution video camera and a wireless transmitter that can be placed on the deminer's helmet, chest, or shoulder as well as wireless receivers and a digital

Image 1. Photo of the SDR chip inside a USB 3.0-to-VGA adapter.

Image 2. A camera is attached to the side of the visor.

video recorder (DVR) at a base station. This enables supervisors to remotely view what the deminers are doing in real time, while also recording the video streams from all deminers. These can be used to help determine the cause of accidents, as well as train deminers under normal circumstances. This work is done in collaboration with the Lebanon Mine Action Center (LMAC), which assisted by providing the logistics to test the DMS in the field.[8]

DEMINING MONITORING SYSTEM DESCRIPTION

The DMS was conceived after several accidents involving deminers occurred over a short period of time during clearance operations. The causes of the incidents were hard to determine, which delayed further clearance work and complicated the work of the insurance companies expected to pay compensations to the injured deminers. The monitoring system comprises two main subsystems: the video-streaming subsystem and the base station. Each deminer is equipped with a video-streaming subsystem. The base station receives and records the video streams from all deminers, and has the ability to forward the video to remote locations such as the headquarters of the demining group.

VIDEO-STREAMING SUBSYSTEM

The video-streaming subsystems consist of high-quality digital cameras connected to single-board computers (SBCs). Also connected to each SBC is a software-defined radio (SDR), which is a radio-communication system. The components of this system are implemented on a general-purpose embedded system using software, instead of being implemented as special-purpose hardware.[9] Examples of such components include mixers, filters, modulators, and demodulators to name a few. The main advantage of the SDR is that some of its functions can be changed or upgraded during operation via software, without the need to change the hardware. In our video-streaming subsystems, SDR output is connected to a power amplifier interfaced to a transmitting antenna. A lightweight battery directly powers the SBC and the power amplifier, whereas the SDR is powered by the SBC. A diagram of the video-streaming subsystem is shown in Figure 1.

The SBC receives the digital-data stream from the camera and runs Python, a programming language that controls the function of the SDR. With the help of Python, the SDR takes the camera's video stream and transforms it into a Digital Video Broadcast-Terrestrial (DVB-T) transmission, which is fed to the input of the power amplifier. DVB-T is the European Standard for the transmission of digital terrestrial television, which has proven to be a successful and reliable digital video transmission standard. The amplifier augments the power of the transmission, allowing it to reach longer distances, beyond the safety distance set between deminers and supervisors. The antenna at the output of the amplifier transmits the signal into the air.

The SDR not only enables the selection of the transmission standard (DVB-T in this case) via software but also allows the operator to set the transmission frequency using this software. The ability to

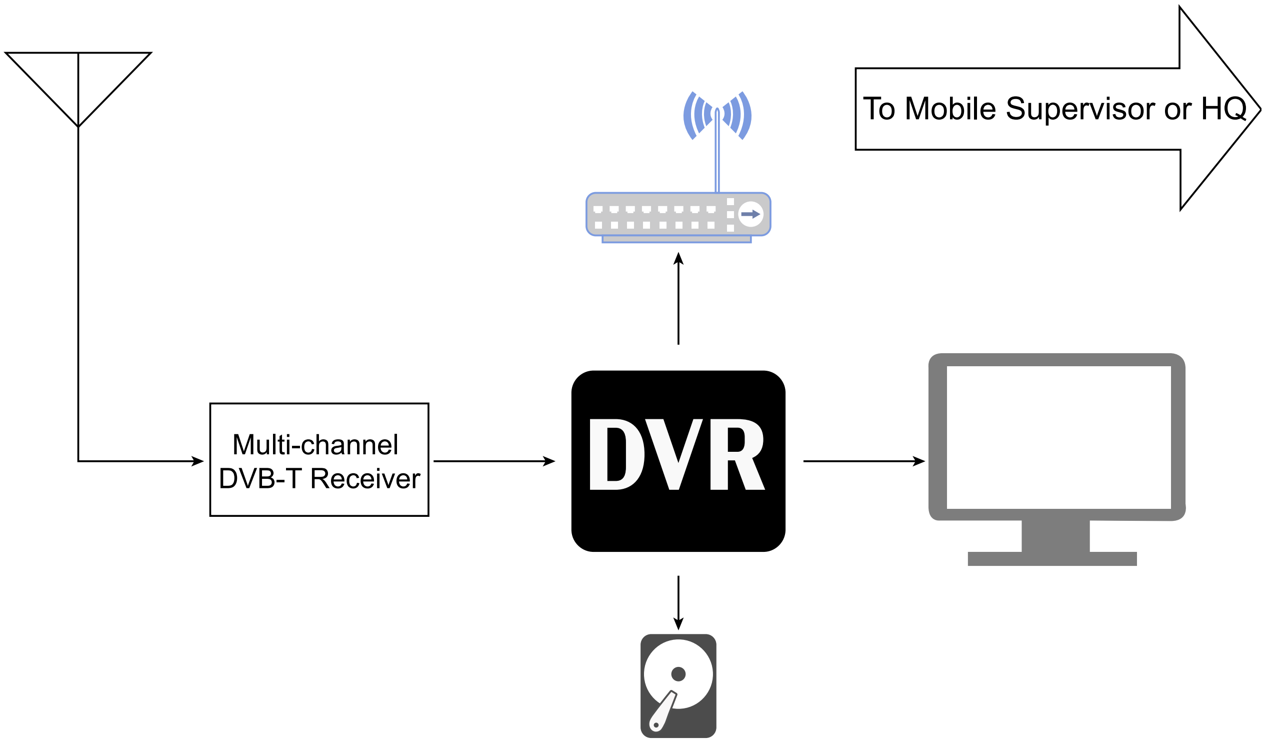

Figure 2. Diagram showing the components of the base station.

select the transmission frequency is essential to distinguishing the channels of the different deminers' video streams, thus limiting interference and also allowing the operator to choose the frequency band for the whole system operation. DVB-T offers improved picture quality and spectral efficiency, which is essential for the demining application when there are transmissions from several deminers at the same time in a small geographical area. DVB-T is also power-efficient, which is a plus for our application, since the transmitter is equipped with only a lightweight battery.

SBCs are ubiquitous and inexpensive. For example, a Raspberry Pi Zero costs only a few dollars. Moreover, SDRs are becoming less expensive and widespread. An inexpensive SDR chip is available in a USB 3.0-to-VGA adapter and is used in the video-streaming subsystem. A photo of the SDR chip inside a USB 3.0 to VGA adapter is shown in Image 1. The selection of these components also helps to keep the overall cost of the system below an acceptable threshold.

The camera can be attached to the visor, on the shoulder of the deminer, or on their chest. The other components (SBC, SDR, and amplifier) are all housed in a small box, which can be mounted on the back of the deminer's vest. A cable runs from the camera to the components box. The antenna can be a simple monopole directly connected to this box or can be a specially-designed wearable-patch antenna made on the back of the vest. Image 2 shows a photo of a camera connected to the side of a visor. A positioning feature (using GPS or similar services) can also be added to this subsystem to pinpoint the locations of each deminer at the time of recording.

BASE STATION SUBSYSTEM

The base station comprises a multi-channel DVB-T receiver connected to a DVR. The DVR has a hard disk installed inside it, which is where the different streams are recorded. A second output of the DVB-T is connected to a monitor to view the different streams in a grid, with the ability to select the number of viewed streams or view only one of them maximized on the monitor. An antenna is attached at the input of the DVB-T receiver. Since the received signals have very low powers, a high-gain antenna should be used as a receiver, and should be capable of picking up signals from wide-azimuth angles. A high-gain monopole antenna can be used, but for better performance, a single-module slotted-waveguide antenna,[10] or its lighter and printed counterpart, the substrate-integrated waveguide antenna,[11] can be employed instead. The estimated time delay between the camera taking the video and viewing the video on the base-station monitor is about 300 milliseconds (0.3 seconds), which gives the feel of real-time viewing. The base station also has the ability to forward the received streams via WiFi or a 4G network to either a mobile supervisor with a laptop or tablet, or to a remote location such as the headquarters of the demining group. Figure 2 shows the components of the base-station subsystem.

DESIGN CHALLENGES

Several cameras with video-streaming capabilities already exist in the market. However, these devices are not suitable for mine action. The main reason is that most of these devices use the WiFi standard for their transmissions, which limits their coverage distance to below the safety distance imposed in demining. The devices that operate in the ultra-high frequency (UHF) band are mostly analog, which makes them prone to external noise. Moreover, the picture quality degrades due to obstacles like hills and vegetation. The second issue with UHF streaming is the limited band, which does not allow several transmissions from different deminers in separate channels.

A solution is to use SDRs to program each camera subsystem to transmit at different frequencies, and to select the band in which the whole system (base station plus all transmitters) operates. This is useful for the operators to select the frequency band that they are allowed to use. Employing DVB-T, which is a digital system, gives users all the advantages of DVB-T including spectral and power efficiency, in addition to noise resistance and operational functionality in rough terrain and thick vegetation. Furthermore, in devising this solution, the authors sought to keep the system cost low, which translated into the selection of inexpensive albeit quality components.

CONCLUSION

A first prototype of the system has already been assembled but is still ongoing lab testing and fine-tuning. An additional field test, with the help of LMAC, is scheduled for the first quarter of 2020. A ruggedized industrial-grade prototype will be fabricated afterward and will also be field tested. Different demining agencies will inspect this new prototype to poll their opinions on the functioning of the system, areas in which it could be improved, additional features to be added, and more importantly, the practicality of the system in real-life demining contexts.

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Masoud Alipour, Ph.D., obtained his doctorate from the Swiss Federal Institute of Technology, Lausanne, Switzerland, in computer science and telecommunications in 2013. His thesis mainly addressed the applications of rateless codes in content synchronization. Alipour has since worked on both theoretical and practical aspects of wireless transmission, channel coding and software defined radio. He has realized a few prototypes in embedded systems and RF transmission. Alipour's research interest include edge computing, telecommunication systems, and software defined radio.

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