EXPERIMENTS ON USING THERMAL IMAGING CAMERA FOR FIRE FIGHTING ACTIVITY

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ABSTRACT

Thermal imaging cameras translate infrared radiation into a viewable image, which shows differences in the temperature in the scene. Thermal imaging cameras have the ability to see in smoke and mist when properly used. Thermal imaging cameras have potential to become a tool in the fire service to increase effectiveness of the present operational methods. A prototype of a wearable thermal imaging camera system was developed and tested. It consists of a helmet-mounted thermal imaging camera, a head-mounted display, batteries, a wireless LAN unit for transferring data to a personal computer, and a video cable for sending thermal images to a videocassette recorder. Two series of tests were done.

In test 1 a compartment (6 m x 6 m x 2.3 m) was filled with smoke generated by smoke candles. A firefighter equipped with a wearable thermal imaging camera system entered the compartment with a lack of visibility caused by smoke. Heat sources were searched.

In test 2 wood cribs were burned in a compartment. Water mist was applied from the outside of the compartment so that the crib fire was almost extinguished. A firefighter equipped with a wearable thermal imaging camera system entered the compartment with a lack of visibility caused by smoke, mist, and vapor. Heat sources remaining on the cribs were searched.

KEYWORDS: Thermal imaging camera, Helmet-mounted, Visibility in smoke

INTRODUCTION

Objects can emit infrared light as well as emitting or reflecting visible light. Thermal imaging cameras translate infrared radiation into a viewable image, which shows differences in the temperature in the scene. Visible light has a relatively short wavelength. This wavelength is susceptible to interference from small airborne particles, such as the carbon particles in smoke or the water droplets in fog. Infrared light has a longer wavelength than visible light. The longer wavelength is not easily reflected by small particles. Therefore thermal imaging cameras have the ability to see in smoke and mist when properly used. Firefighters must enter a structure with a lack of visibility caused by smoke created by fire. Thermal imaging cameras have potential to become a tool in the fire service to increase effectiveness of the present operational methods. Little has been written on thermal imaging cameras for firefighter use; it was mentioned in a few books[1, 2] and some journal articles[3-11]. These works[1-9] explain what thermal imaging is, how to use it effectively on the fire ground and as a tactical tool in other emergency incidents, and the limitations of such systems. Criteria for choosing a thermal imaging camera suited for the fire service are shown in references 10 and 11. National Institute of Standards and Technology (NIST) built a facility to permit the development of standard test protocols and quantitative metrics to evaluate performance of thermal imaging cameras. Effect of water sprays on performance of thermal imaging cameras was investigated under non-fire conditions[12]. NIST held a workshop which provided a forum to discuss the strategies, technologies, procedures, best practices, research, and development that could improve thermal imaging technology for the first responder community[13].

With technology growing at a fast pace, thermal imaging cameras can be manufactured so that they are small and light compared with before. A prototype of a wearable thermal imaging camera system was developed. The system shown in this paper offers the advantage of keeping the firefighter's hands free while operating. A thermal imaging camera is mounted on a helmet. Thermal images are seen by a head-mounted display attached on the helmet. Also the thermal images are sent to videocassette recorder by a video cable and a personal computer by wireless LAN. A firefighter with the system enters smoke-filled room and does firefighting operations.

EXPERIMENTAL

A prototype of a wearable thermal imaging camera system was developed and tested. It consists of a helmet-mounted thermal imaging camera, a head-mounted display, batteries, a wireless LAN unit for transferring data to a personal computer, and a video cable for sending thermal images to a videocassette recorder. Outline of the system is shown schematically in Fig. 1. Fig. 2 shows a firefighter with the system. A thermal image camera is mounted on a helmet. Its properties are shown in Table 1. Its power is supplied by a power cable from a battery stored in a pouch attached to the waist of the firefighter. Thermal images are sent by a video cable to an instrument in the pouch and are distributed into three. One is sent to head-mounted display which is mounted on the helmet. The firefighter can see the thermal images using the display. As shown in Fig. 2, head-mounted display is attached outside of the face piece of the firefighter. Operation temperature of the head mounted display is between zero and 60 ˚C. Second is sent by a video cable to a videocassette recorder. Third is sent by a video cable to a wireless LAN unit. It is transmitted to a personal computer.

Two series of tests were done. Details of the experiments are shown in the previous papers[14-16]. The test apparatus employed for this series of experiments is illustrated in Fig. 3. Dimensions of the fire room are 6 m in width, 6 m in depth, and 2.4 m in height. The fire room is made of metal plate, except that lower part of one side wall is made of calcium silicate board for emergency escape from the room. The fire room has an opening whose dimensions are 0.9 m in width and 1.8 m in height. A video camera and a thermal imaging camera are placed near the opening to observe inside of the room through the opening. Five to ten meters behind the opening, a video camera is placed to record outlook of experiments. Two series of tests were done.

Test 1

Test 1 is done in non-fire conditions. Two smoke candles and twelve cups filled with hot water are placed on the floor of the fire room. The fire room is filled with smoke generated by the smoke candles. A firefighter equipped with a wearable thermal imaging camera system entered the room with a lack of visibility caused by smoke and search for heat source.

Test 2

Test 2 is done in fire conditions. Two wood cribs are placed in the fire room. A wood crib used is second type for Class A fire based on the Japanese Fire Service Law. The cribs are ignited by a flame of heptane pool fire. Three minutes after ignition, water mist is applied using a hand line. The line is fitted with a water mist nozzle[17]. Water (flow rate=40 dm^3/min) and compressed air (flow rate = 1000 dm^3/min) are mixed and ejected through the nozzle. After stopping water application, a firefighter equipped with a wearable thermal imaging camera system entered the room with a lack of visibility caused by smoke, mist and vapor. The wood cribs are extinguished completely using the hand line if necessary.

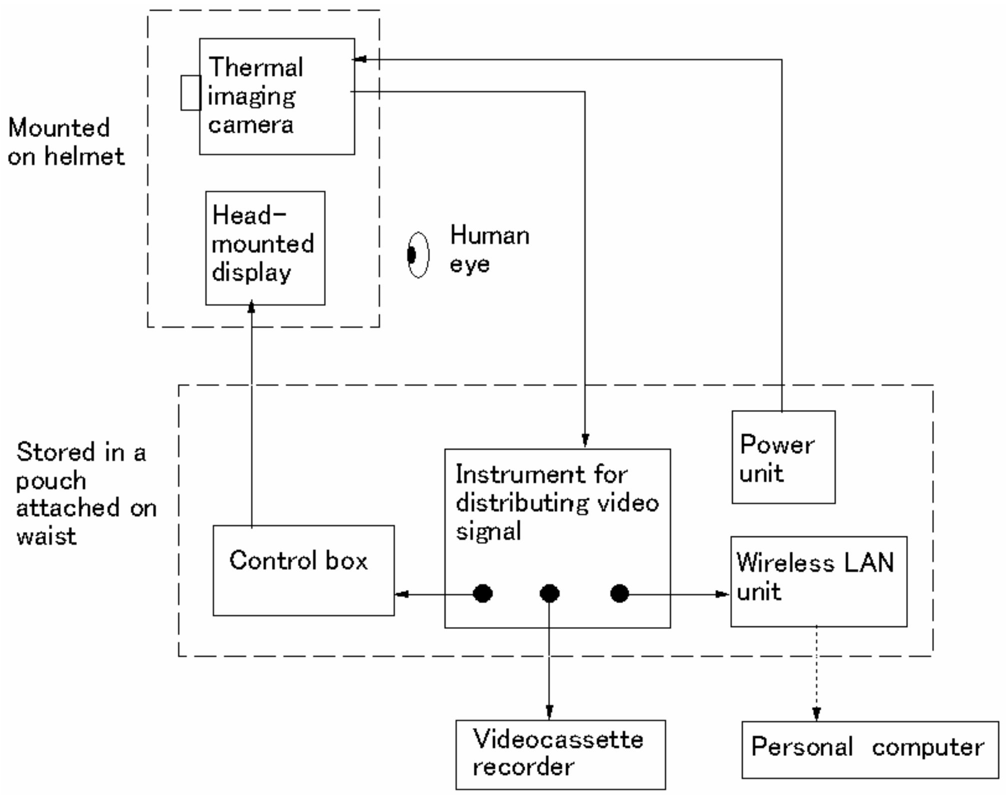


FIGURE 1. Outline of wearable thermal imaging camera system

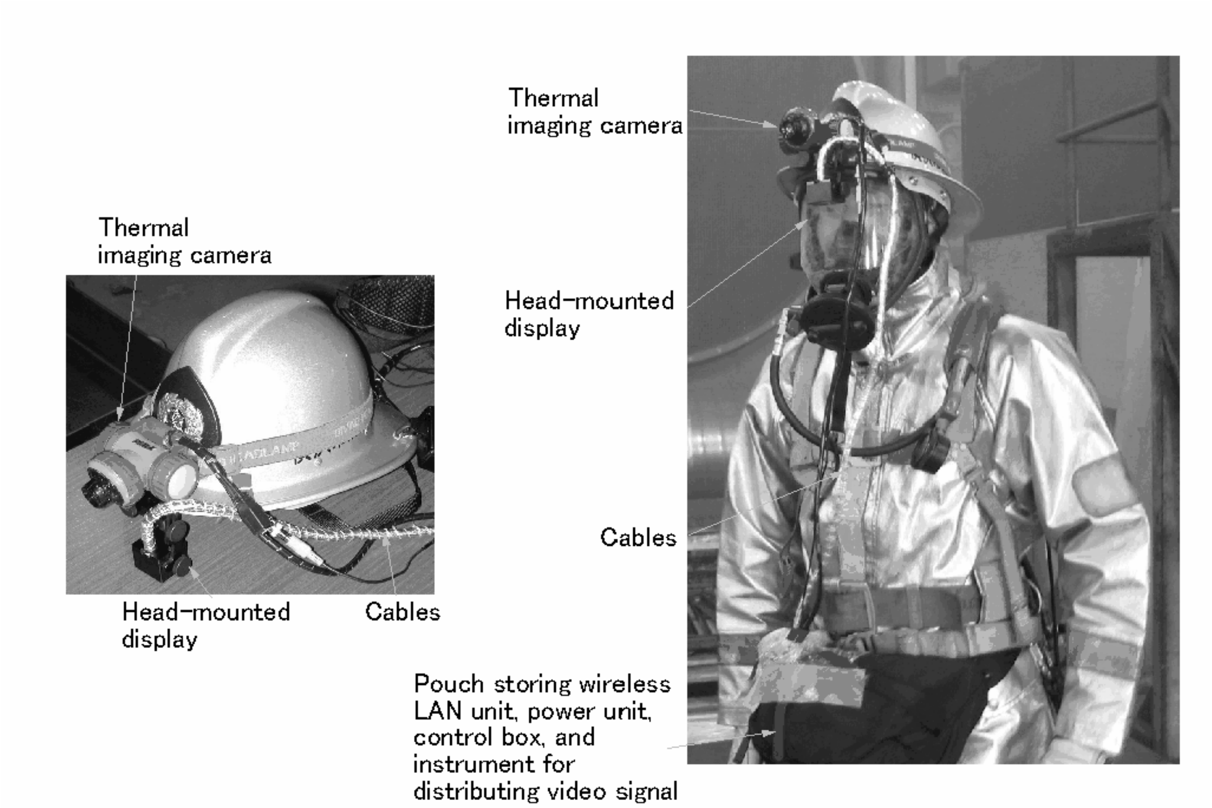


FIGURE 2. Firefighter with wearable thermal imaging camera system

TABLE 1. Properties of helmet-mounted thermal imaging camera

Feature	Properties
Detector (number of pixels)	Microbolometer (160 x 120)
Wavelength	7-14 µm
Sensitivity	0.05 ˚C
Frame time	30 frames/s
Field of view	50˚ x 37˚
Interface	NTSC video output
Operation temperature	-20 ˚C to 85 ˚C
Weight	260 g

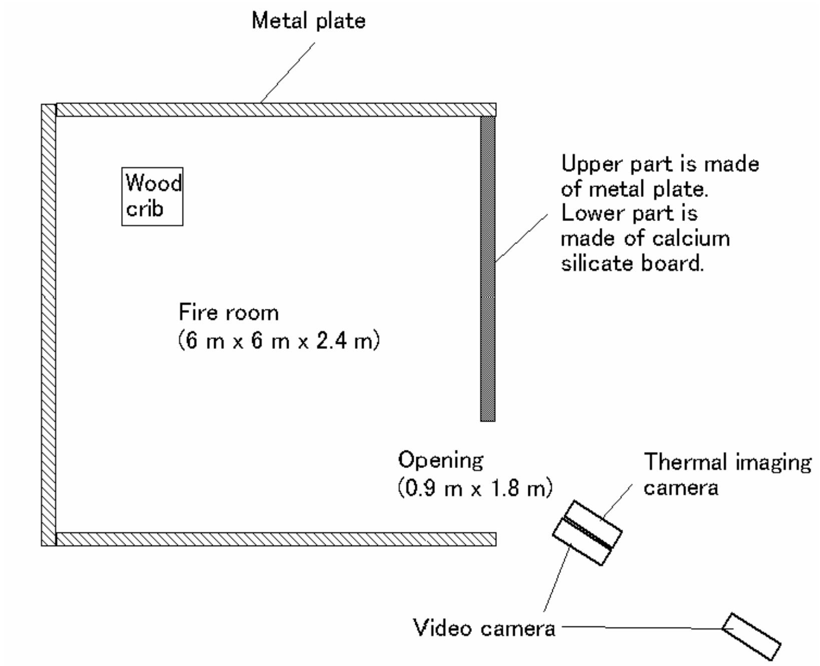


FIGURE 3. Experimental setup (Not to scale)

RESULTS AND DISCUSSIONS

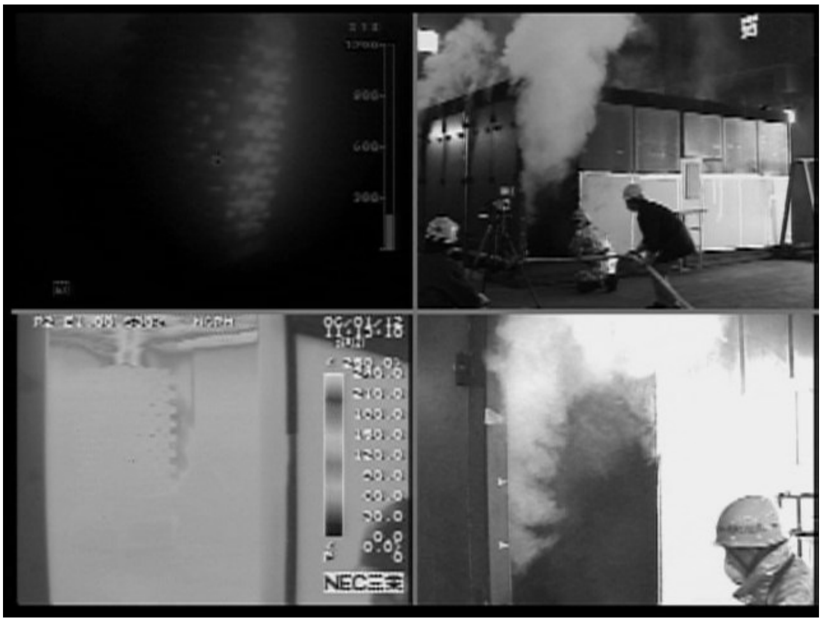
Thermal images were sent to videocassette recorder by a video cable and transmitted to personal computer by wireless LAN. Images taken by video cameras and thermal image cameras were mixed by a video mixer and recorded by a videocassette recorder. Mixed images are shown in Fig. 4.

Test 1
The fire room was filled with smoke and visibility was zero. Firefighter scanned inside of the fire room through the opening as shown in Fig. 4(a). Locations of smoke candles and cups were identified. The firefighter entered the room. The firefighter could walk on the floor avoiding cups using video images sent from the helmet-mounted thermal image camera. Also the firefighter could know exact location of cups and take a cup in the hand. The firefighter could identify the opening and came out from the fire room.

Test 2
Before starting water application, upper half of the fire room was filled with hot smoky gas and lower half was clear. After starting water application, smoky layer went down quickly. In less than ten seconds visibility was lost. Water application was continued for two to three minutes. When it was considered that the fire room temperature was low enough to make entry, water application was stopped and entry was made. The firefighter found red glowing part remained on the cribs and

extinguished by water application. Thermal images in the room were taken clearly with head-mounted thermal image camera. The cribs which were still hot were identified as shown in Fig. 4(b). However the firefighter could not see thermal images using the head-mounted display. At first it was thought that fire room temperature was too hot for the head-mounted display to operate. But afterwards it was considered that the head-mounted display was fogged because of condensation of water vapor on the display.

(a) Test 1. The fire room is filled with smoke and visibility is zero. Firefighter scans inside of the fire room through the opening. Locations of smoke candles and cups are identified.



(b) Test 2. The fire room is filled with smoke and vapor. Firefighter entered the fire room with a lack of visibility and scans it. Wood crib is identified. A part of the wood crib is still hot.

FIGURE 4. Images taken by cameras
Upper left: thermal image taken by the helmet-mounted thermal image camera. Upper right: visible image taken by the video camera behind the opening. Lower left: thermal image taken by the thermal image camera near the opening. Lower right: visible image taken by the video camera near the opening.

Potential of a wearable thermal imaging camera system for the fire service was shown. However problems to be solved before using it in fire fighting operations were also shown. Following problems were found. 1) When a firefighter applied water to a fire, the head-mounted display fogged. It is needed that condensation of water vapor on the head-mounted display is prevented. Until the head-mounted display is moved inside the face piece, there will be a problem with fogging. 2) Images shown on head-mounted display was not large enough for the firefighter equipped with wearable thermal imaging camera system to see with ease. It is needed that the distance between an eye and the head-mounted display is adjusted. 3) A head-mounted display may not tolerate high heat conditions in firefighting activities since operation temperature of the display is between zero and 60 ˚C.

CONCLUSIONS

A prototype of a wearable thermal imaging camera system was developed and tested. It consists of a helmet-mounted thermal imaging camera, a head-mounted display, batteries, a wireless LAN unit for transferring data to a personal computer, and a video cable for sending thermal images to a videocassette recorder. Two series of tests were done in non-fire conditions and in fire conditions.

In test 1 a fire room (6 m x 6 m x 2.3 m) was filled with smoke generated by smoke candles. A firefighter equipped with a wearable thermal imaging camera system entered the room with a lack of visibility caused by smoke. Heat sources in the room were identified by the helmet-mounted thermal imaging camera.

In test 2 wood cribs were burned in a compartment. Water mist was applied from the outside of the fire room so that the crib fire was almost extinguished. A firefighter equipped with a wearable thermal imaging camera system entered the room with a lack of visibility caused by smoke, mist, and water vapor. Heat sources remaining on the cribs were seen in the thermal images taken by the helmet-mounted thermal imaging camera.

Potential of a wearable thermal imaging camera system for the fire service was shown. However problems to be solved before using it in fire fighting operations were also shown.

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