# A STUDY OF FIRST RESPONDERS' USE OF DIGITAL CAMERAS FOR DOCUMENTING RESCUE OPERATIONS FOR DEBRIEFING AND ANALYSIS

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## Abstract
Incident commanders at the Linköping Fire Department in Sweden used digital cameras to document rescue operations for 15 months. They shared the photographs with their colleagues and managers through a database on the local network of the main fire station. We describe the hardware and software used and present initial results regarding their use for documenting and analyzing rescue operations. We also give a specific example of how responders used digital photographs to reconstruct the course of events of a major fire in a factory building and how the resulting time line facilitated the analysis of the incident.

## Introduction
Learning from experience is essential for developing professional proficiency. However, just experiencing is not sufficient for learning to take place. On the contrary, learning from experience requires a conscious effort from the learner to reflect on the actions performed and their results. This reflection often requires the aid both by artifacts to facilitate cognition and by interaction with other people. The purpose of reflection is to structure the experience, to make sense of it, and to draw conclusions for further development and improvement. A major problem in the reflective analysis of past operations is to establish the sequence of significant events. Reconstructing timelines of operations is crucial, yet surprisingly difficult.

Most efforts to promote reflection in experienced-based learning have been directed toward training settings. However, there is a great need to incorporate support for analyzing real operations and disseminating the lessons learned. In 2001, the Swedish Defence Research Agency initiated a research project together with the Swedish Rescue Services Agency and the Linköping Fire Department with the goal to help responders in the rescue community to systematically learn from real operations (Jenvald, Johansson, Nygren & Palmgren, 2001). To this end, the project team developed methods and tools for reconstructing rescue operations and customized them for use by first responders in real operations. Thorstensson (2002) described how methods developed for training support could be adapted and applied in an operational setting. This paper presents initial results from this transition. Specifically, we investigate how

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first responders at the Linköping Fire Department used digital cameras to document and analyze rescue operations during 15 months in 2002 and 2003.

The paper is organized in the following way. The next section provides the theoretical foundation for this study. Then follow two sections that describe the methods used in the investigation and present the key findings, respectively. A discussion of the findings and our conclusions complete the paper.

## Theory

Participants in complex, dynamic situations are thrown into action with limited possibility to step back and reflect on actions as the situation unfolds (Winograd & Flores, 1986). After the action, on the other hand, it is essential that they reflect on the experience as a basis for further development. Kolb (1984) emphasized the combination of concrete here-and-now experience with the use of feedback to change practices and theories. Checkland and Scholes (1990) provided a similar account of the interplay between purposeful action in the world, experience, and experience-based knowledge. Norman (1993) noted that reflection on performance makes it possible to better know what to change and what to keep. Effective processing requires accurate feedback on the actions taken, which is often a problem in dynamic and distributed environments, such as rescue operations, where the actor may not see the effects of his or her actions (Hoffman, Crandall & Shadbolt, 1998) and where the environment may change state spontaneously, without deliberate intervention (Wærn, 1998).

Debriefing provides an opportunity to engage in structured reflection on an experience in order to modify behavior based on that experience (Pearson & Smith, 1986; Raths, 1987; Lederman, 1992). In training, debriefing is commonly referred to as after-action review (Hoare, 1996). To provide effective feedback, methods and tools to present representations of operations have been developed and used to support after-action reviews in military settings (Morrison & Meliza, 1999) as well as in emergency management and response (Slepow, Petty & Kincaid, 1997; Jenvald, 1999). Morin and his colleagues (Morin, Jenvald & Thorstensson, 2000) described how models of rescue operations built from multiple sources of data could support analysis and feedback. Applications of this method include training for chemical incidents (Morin, Jenvald & Worm, 1998; Crissey, Morin & Jenvald, 2001) and underground accidents (Thorstensson, Björneberg, Tingland & Tirmén Carelius, 2001), as well as real operations (Morin, 2002). Specifically, it has been used to investigate communication in the command and control of rescue operations (Thorstensson, Axelsson, Morin & Jenvald, 2001; Albinsson & Morin, 2002).

Thorstensson (2002) argued that methods and tools from the training domain could be adapted and applied to live operations. He further pointed out the need to use automatic procedures, whenever possible, in order not to divert the attention of the rescue personnel from their primary task. Nevertheless, observations made by the rescue crew in the course of the operation can provide information crucial for performance feedback and analysis. It is essential to incorporate dedicated observation procedures, but to do it in an unobtrusive manner.

## Method

We investigated the use of digital cameras at the Linköping Fire Department in Sweden during 449 days in 2002 and 2003. Linköping municipality (population: 130,000) has one main fire station with three fire-rescue units and six satellite stations with one fire-rescue unit each. A fire-rescue unit typically consists of a unit leader with two to six firefighters and one or two fire trucks. In addition, there is always an operations officer and a station officer on call and a senior officer on duty (see Table 1). In the Swedish incident command system there is always an incident commander regardless of the size of the responding rescue force. In a one-unit operation, the unit leader becomes incident commander. When more than one unit is involved, the operations officer typically assumes this role. In large operations, the senior officer on duty takes command. The standard response to an alarm in the case of a suspected fire is two units commanded by the operations officer.

Table 1: Personnel categories and operational roles at Linköping Fire Department

| Category | Operational role |
|---|---|
| Senior officer | Responds to and assumes command of incidents that require several units, take a long time, or are otherwise complex or unusual. He drives a command vehicle with room for a small field command post. |
| Operations officer | Responds to alarms that require more than one unit, travels in his own command vehicle (ahead of the fire trucks), and is incident commander |
| Station officer | Heads the command center at the main fire station, receives alarms, and organizes the responding force depending on the type of incident |
| Unit leader | Leads a fire-rescue unit and is incident commander in one-unit response |
| Firefighter | Is a first responder in a fire-rescue unit |

For the study, we equipped the command vehicle of the operations officer on call with a digital camera that included a clock. We also developed the PIX software to upload digital photographs from the camera to a picture server in the local network at the main fire station. We used the Canon Digital Ixus V camera and developed an interface to PIX using the software development kit for that camera series. The PIX server organizes the photographs according to their associated timestamp and maintains information about the incident and the photographer. It also includes annotations provided by the photographer. Using the PIX client program, the personnel at the fire station can connect to the server and watch the photographs from a particular incident. It is also possible to copy pictures to standard formats and programs. The 13 operations officers at Linköping Fire Department received two hours of training on how to operate the cameras and the software. However, they did not get any specific instructions on when to take pictures or what subjects to choose. The study includes data collected between January 16, 2002 and April 9, 2003.

To find out how the operations officers used the camera to document incidents, we examined the picture database in the PIX server. We cross-referenced the picture data with excerpts from the log of all operations, kept in the command center at the main fire station, to establish a classification of the incidents and to link the picture data to the type of incident. The log lists all alarms chronologically with information about the type of incident, the location, the type of object, and the incident commander.

In the second part of the study, we classified all photographs in the database according to their subjects. The categories used were (a) rescue activities, (b) dynamic situation, (c) cause of incident, (d) damage, (e) environment of damage, and (f) other. The class for rescue activities includes all pictures capturing fire trucks, equipment, and firefighters. The dynamic situation class covers snapshots of the incident scene that captures the development of the dynamic situation. Photographs classified as cause of incident typically show a detail from the incident scene and have annotations that indicate a hypothetical cause of the incident. The damage class comprises pictures that show the consequences of an incident. Photographs classified as environment of damage provide additional information about the place where the damage occurred or its surroundings, but do not show actual damages.

For the last part of the study, we interviewed the senior officer acting as incident commander at a major fire in an industrial building. We asked questions regarding the use of digital photographs in the aftermath of the fire. We also reviewed the timeline of the incident reconstructed from the digital photographs and other documentation produced at the forward command post and at the command center.

## Results

During the 449 days that we studied between January 16, 2002, and April 9, 2003, the Linköping Fire Department responded to 1831 alarms (see Table 2). From the total number of calls in that period, we extracted the calls where an operations officer responded. From these, we excluded all alarms not caused by fire but generated by automatic fire detection systems. The reason for excluding these alarms is that they neither represented a threat to life or property, nor required any other response than checking the fire detection system and filing a report. The remaining 251 alarms prompted a response from the operations officer on call and required some sort of action from the rescue force that was, potentially, interesting to document with the digital camera. In Table 2, we see that the alarms included in the study represent less than 14 percent of the total number of alarms.

Table 2: Classification of the alarms during the period of the study

| Type of alarm | Number | Percent |
|---|---|---|
| All alarms | 1831 | 100.0 |
| Alarms to which an operations officer responded | 912 | 49.8 |
| Alarms to which an operations officer responded that were not caused by fire but generated by automatic fire detection systems | 661 | 36.1 |
| Alarms to which an operations officer responded that were related to fire or suspected fire | 178 | 9.7 |
| Alarms to which an operations officer responded that were related to traffic incidents | 36 | 2.0 |
| Alarms to which an operations officer responded that were related to incidents other than fire or traffic | 37 | 2.0 |

From the classification of alarms in the log of operations, we divided the 251 incidents into three categories: (1) fire or suspected fire, (2) traffic accidents, and (3) others. The third category includes all kinds of odd jobs assigned to the fire department—for example, removing oil spill from roads, repairing leaking water pipes, and assisting the police in recovering dead bodies. Table 3 lists the categories and the number of incidents in each category. Furthermore, by examining the database in the PIX server, we identified the incidents in each category that had associated photographs. Table 3 gives the number of incidents with associated photographs and the corresponding percentage of the total number of incidents in each category. On average, the operations officers used the digital camera in 29.5 percent of the incidents. In fire-related incidents, the corresponding number is close to 33 percent, and in traffic incidents, it is nearly 39 percent.

Table 3: The use of digital cameras

| Incident category | Number of incidents | Number of incidents with camera use | Percent of incidents with camera use |
|---|---|---|---|
| Fire or suspected fire | 178 | 58 | 32.6 |
| Traffic accident | 36 | 14 | 38.9 |
| Other | 37 | 2 | 5.4 |
| All | 251 | 74 | 29.5 |

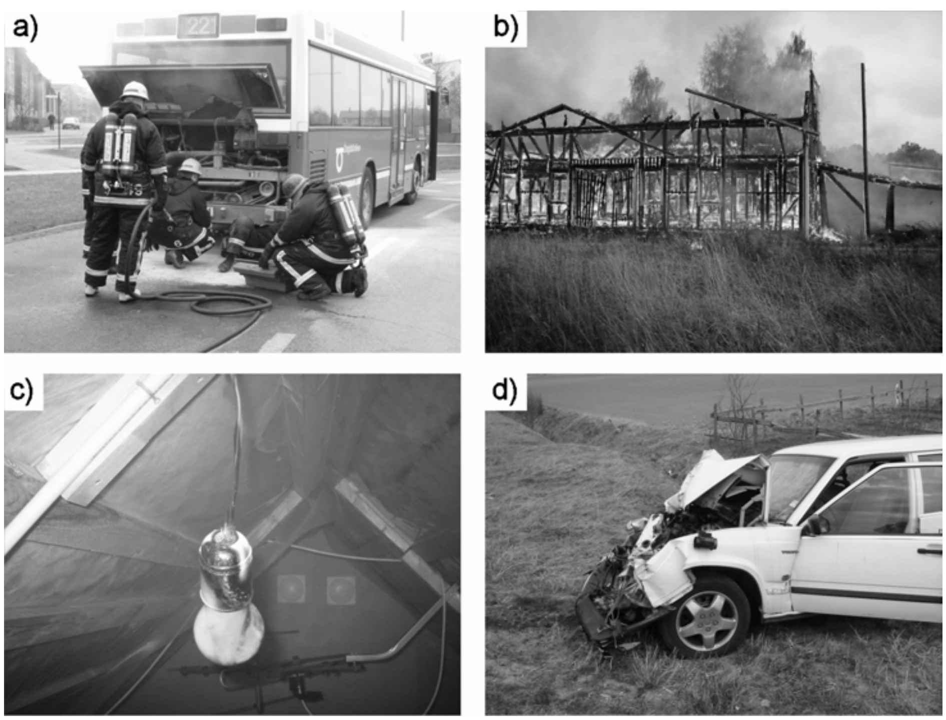
There were considerable differences among the 13 operations officers regarding how they used the digital camera. We partitioned the data from the operations officers according to the percent of incidents they used the digital camera. This analysis resulted in a median of 31 percent, whereas the upper and lower quartiles were 49 and 7.4 percent, respectively.

Table 4: Classification of photographs according to subject

| Subject of photograph | Number of photographs | Percent of total number |
|---|---|---|
| Rescue activity (a) | 144 | 28.6 |
| Dynamic situation (b) | 69 | 13.7 |
| Cause of incident (c) | 53 | 10.5 |
| Damage (d) | 172 | 34.2 |
| Environment of damage (e) | 58 | 11.5 |
| Other (f) | 7 | 1.4 |
| Total | 503 | 100.0 |

Turning to the contents of the photographs, we classified the 503 pictures in the database using the classes in Table 4. Figure 1 shows four photographs from the PIX database as examples of the classification: rescue activity (a), dynamic situation (b), cause of incident (c), and damage (d). The average number of pictures taken in the 74 incidents documented was 6.8. The median was 4, whereas the upper and lower quartiles were 17 and 2, respectively. Thus, in a large proportion of the incidents the operations officer used only a few pictures to document the rescue operation. In those cases, the photographs typically captured the cause of the incident, the damage, and the environment of the damage. Photographs classified as rescue activity and dynamic situation typically appear in operations documented with many pictures.

Figure 1: Examples of classification of photographs



Finally, we describe how an incident commander and fire investigators used digital photographs to support analysis and feedback after a major fire. At 13:07 on February 14, 2003, the Linköping Fire Department received an alarm concerning a fire in a building containing a rust-protection industry and offices. The operations officer on call headed to the scene in his command vehicle followed by two fire-rescue units in three fire trucks. When the operations officer approached the incident scene, he reported a huge column of smoke. The senior officer on duty and two additional fire-rescue units deployed as a result of this indication. Twenty-five officers, unit leaders, and firefighters participated in the response on scene and three officers supported the station officer at the command center. The emergency response to the incident ceased at 19:26, but the main effort was completed at 17:30.

Figure 2 shows a timeline of the operation reconstructed from incident log files and digital photographs. The operation consisted of five phases. In the initial phase (P1), the first responding units entered the building from the back to remove gas cylinders. The second phase (P2) included an attempt to fight the fire in the rust-protection workshop both from the inside of the building and from the outside. When that attempt failed, the third phase (P3) began. The aim defined for this phase was to contain the fire in the workshop building by fighting the fire from the roof and from the inside of the office part of the building. Again, the attempt was in vain and the incident commander decided to use an excavator to dig a firebreak through the building. Phase four (P4) included this procedure and the subsequent extinction of the fire. Phase five (P5) was the final work to make sure that the building was secured. Figure 2 displays two photographs from the PIX database that present different techniques for putting out fire used in different phases of the operation.

<u>Figure 2: Timeline of the rescue operation</u>

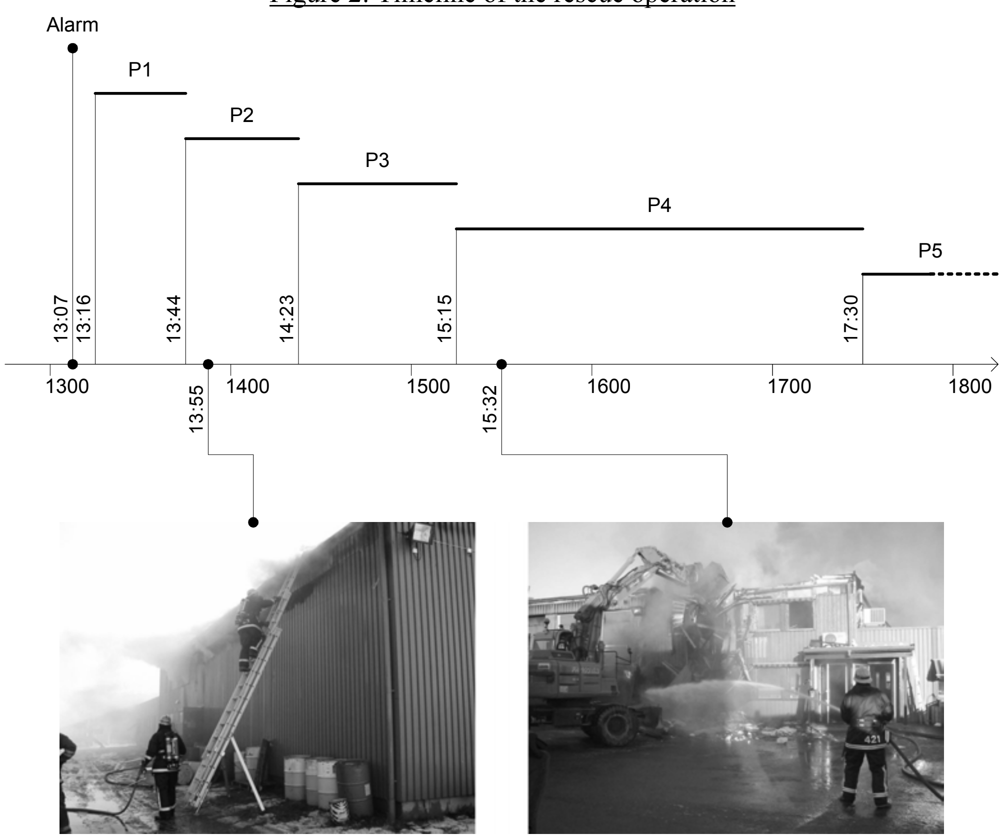


Table 5: Use of digital photographs from the incident for analysis and feedback

| Date | Users | Description |
|---|---|---|
| February 15 | Incident commander (senior officer on duty) | Reconstruction of the course of events the day after the incident and reflection on the development |
| February 17 | Incident commander, operations officer, station officer, and command staff | Walkthrough of the course of events, evaluation of the response, lessons learned |
| February 19 | Incident commander, officers, and unit leaders | Walkthrough of the course of events, evaluation of the response, lessons learned |
| February 19 | Incident commander, firefighters who participated | Walkthrough of the course of events, evaluation of the response, lessons learned |
| February–March | Incident commander, unit leaders and firefighters who did not participate | Walkthrough of the course of events, evaluation of the response, lessons learned |
| February 14–(in progress) | Fire investigator and police | Photographs support the reconstruction of the dynamic development to establish the cause of the fire |
| May 14 | Incident commander, owner of the property, insurance company | Walkthrough of the course of events, explanation of the measures taken to fight the fire |

After the operation, the incident commander and the operations officer entered their photographs and text annotations into the PIX database. Table 5 lists a number of occasions where the digital photographs were used support analysis and feedback for various groups of users.

## Discussion

In approximately 30 percent of the incidents the operations officers decided to use the digital camera to document some aspect of the rescue operation. This number indicates that operations officers find the digital camera useful in rescue operations. Whether this number adequately reflects the number of potentially interesting situations worthwhile to document is a difficult question. To answer the question, we must consider the purpose of documentation, the circumstances of the particular operation, and the individual's skills and motives.

Our study presents individual differences among the 13 operations officers when it comes to their use of the digital camera in rescue operations. An explanation for this difference can be that officers hold different opinions on what subjects are worthwhile photographing. Their ability to use technical artifacts and systems may also differ. Some of the officers may find that taking photographs in the course of an operation adds to their cognitive workload in an unacceptable manner. How useful the officers consider the resulting photographs may affect the frequency and explain some of the differences found among the individuals. Another factor to regard is whether the operations officers have additional responsibilities, such as fire investigation or external education and training, where pictures from operations may be useful. The differences raise questions whether there is a need for a refresher course on camera operation and for further demonstrating the utility of systematic documentation of rescue operations. A selection of pictures from the operations documented during the first 15 months can serve as good examples and be used to motivate extended operational use of digital cameras.

Photographing during fire and rescue operations may raise ethical issues on what to take pictures of and what not to document with the camera. At Linköping Fire Department the professional responsibility lies on the individual photographer, who has to decide whether a picture would have a value for the documentation and the evaluation of the rescue operation. The presence of dead or injured people on an incident scene emphasizes these ethical issues. On the one hand, it would be easy to state as a policy that the officers should exclude pictures of victims. On the other hand, pictures of the actual situation may result in improved rescue procedures in the future. For example, if a person is stuck in a car after a traffic accident, the officer may hesitate to take a photograph before extricating the victim. However, a medical doctor may use such a picture to aid diagnosis and treatment, so the information may indeed mean the difference between life and death for that person. Ethical issues are not easy to manage, but managers and officers need to be address and discuss them before starting to use digital cameras to document rescue operations. A policy for camera use is required to support the responders in their role as observers of rescue operations.

Among the lessons learned from the Linköping Fire Department is that there is indeed a need for time-stamped pictures from fire–rescue operations for facilitating the recording and reconstruction of the course of events. The fire department needs this capability to evaluate the units' performance and to support the exchange of ideas and experience between officers, unit leaders, and firefighters. The operational use of digital cameras and the PIX system will continue at Linköping Fire Department. In addition, based on the results in this study, the 13 operations officers will add to their monthly meetings a point in the agenda that includes reports from significant rescue operations. The operations officers will use the digital photographs for illustrating their accounts of the operations they have commanded to help their colleagues understand the situations encountered, although they were not present. Another decision is to integrate and take further advantage of the PIX system to manage pictures in cases of fire investigations in cooperation with the police. An additional lesson learned from this study is that the Linköping Fire Department needs to revise and develop the incident classification system it uses to create the log of operations in the command center.

## Conclusion and future work

This study extends previous research on how to support experience-based learning in workplace settings. By investigating how first responders at the Linköping Fire Department used digital cameras to document rescue operations, we have demonstrated that this source of data is indeed a viable means of data collection in real operations. The photographs taken have facilitated analysis and feedback. However, the group of participants in the study is limited and not necessarily representative for a larger population of operations officers. Therefore, the results cannot be immediately generalized to other emergency response organizations. Nevertheless, the study highlights several important aspects concerning the operational use of digital cameras that should be of general interest. They include the frequency and subjects of the photographs taken, usefulness of pictures for different purposes, individual differences, and last but not least ethical issues.

More research is necessary to investigate these issues. A larger study would include participants from several fire departments, from major cities as well as from smaller communities. Questionnaires or interviews are needed to capture how the officers perceive the utility of digital photographs as well as their reasons for using or not using the camera in particular rescue operations. Our goal is to continue the development of methods and tools together with Linköping Fire Department in order to increase rescue-mission efficiency and to create new and valuable knowledge of international interest.

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