Collaborative Situational Mapping during Emergency Response

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ABSTRACT

During emergency response, individuals observe only part of the picture, sharing of information is needed to get the required complete picture. The aim of our study is to get insight in the collaborative mapping process in order to derive requirements for a map-sharing tool. First, we analyzed the domain to assess the mapping processes, to identify general problem areas of the assessed processes. Subsequently, we conducted a laboratory experiment to systematically investigate the indentified problem of collaborative map construction by individuals who observed an incident from different perspectives.

This paper discuss an experiment, which showed that the individual maps are sometimes better than the jointly constructed map, among other things due to the collaboration biases of unbalanced relations and uncertainty about oneself. Thus based on this experiment, the collaborative mapping tool should support joint map construction and help to prevent the identified collaboration biases.

Keywords

Collaboration, user-centered design, distributed, situation map, disaster response, emergency.

ACM Classification Keywords

H.5.2 [**Information interfaces and presentation**]: User Interfaces (D.2.2, H.1.2, I.3.6) --- User-centered design, Prototyping

1. INTRODUCTION

The effectiveness of emergency response team heavily depends on their response speed, and on how well they can manage their resources. Their aim is to reduce the resulting damage and the impact on human lives. In order to react promptly, the emergency response team needs to have a reliable overview of the disaster situation. This may include accessibility of the road network, the condition of damaged infrastructures, and the status of available resources. This overview, usually provided in the form of geospatial information, is useful to get a clear mental image of the disaster area. Unfortunately, a situation map as such is often difficult to construct. Moreover, it is often the case that the scope of the incident is only understood after several days.

Geo-information technologies such as Geographic Information Systems (GIS) have the potential to provide critical support during disaster response. Situation-maps demonstrated to be an essential collaboration tool in crisis situations [1]. However, this technology is sometimes inefficient in supporting emergency response teams. Occasionally, wrong interaction modalities are used to convey information. For example, many current practices use verbal communication over the phone to describe geo-spatial information, which may result in misunderstandings and inaccurate positioning of objects and events. Furthermore, many geo-information technologies are too complicated to be used without prior training [2], and are usually designed without supporting collaboration in a team.

We aim to investigate the possibility of constructing a shared situation map using a collaborative distributed mechanism. By supporting collaboration among distributed information-sources, it is expected that the first hand information can be easily collected, checked, and shared. Thus, eliminating intermediate communication chains, which in turn may result in faster and more accurate situation maps. The shared situation map can also be used as a communication tool among the actors involved.

The setup of this paper is summarized as follows: first, we describe our field study by observing our users in their working environment and participated in disaster management exercises. Second, we describe our laboratory experiment setup in order to explore the idea of the joint situation map. Based on these things, we formulate guidelines for the collaborative situation map for emergency response.

2. OBSERVATION IN THE SAFETY REGION OF ROTTERDAM-RIJNMOND, THE NETHERLANDS

In the Rotterdam area of the Netherlands, the crisis and disaster management is organized by Safety Region Rotterdam-Rijnmond. The participating agencies are municipalities, the fire service, the ambulance service, the medical emergency service, the police, the dispatch center, the Rotterdam port authority, and the environment protection agency.

We observed the work of this team in their exercises, both at the regional level and nationwide. One of the recent exercises is 'Waterproef', a nationwide disaster exercise in which a flood situation in the Netherlands was simulated. This exercise was held from 30 October to 7 November 2008.

The scaling of incident or disaster is regulated by a national agreement called Coordinated Regional Incident Control Procedure (GRIP). GRIP stages regulate the structure of collaboration of the agencies, based on the scope of the incident. The two main groups are the Incident Command Post (CoPI) and the Operational Team (OT). The CoPI works at the location of the incident while the OT works at the command center in the World Port Center Rotterdam. The CoPI reports the

development of the situation to the OT, and OT updates any strategy changes during the incident. The internal structure of the CoPI and the OT is similar, consisting of representatives from the agencies mentioned above.

2.1 Current Information Sharing

Although members of the CoPI team work together closely and share information, they only report back to their own superior in the OT. For example, the leader of the CoPI reports to the leader of the OT, the police officer in the CoPI reports to his superior in the OT, and so on. The reporting is mainly done by phone. Any geo-spatial information received by the OT member is drawn on a paper map. These maps are collected by a plotter who draws and maintains a shared situation map that can only be shown among the OT. The information sharing of the team can be seen in Figure 1.

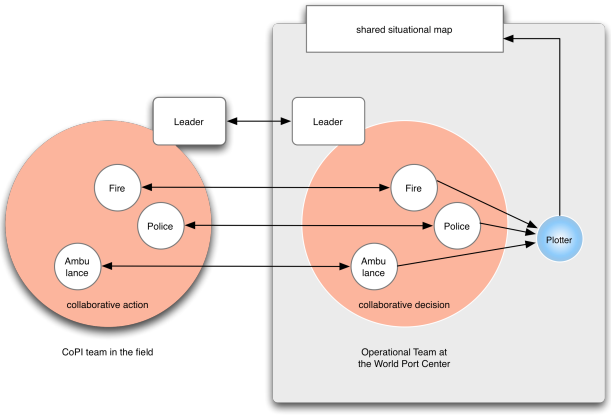


Figure 1. The current information flow and sharing. The collaborative agents are not limited to the fire service, the police, and the ambulance service but including municipalities, the medical emergency service, the dispatch center, the Rotterdam port authority, and the environment protection agency.

2.2 Problems with current information sharing

The plotter often encounters difficulties in putting these reports into the system. This is mainly caused by the complexity of the system. The system consists of several unconnected geo-information technologies running on different terminals, as shown in Figure 2. The plotter needs several hours of training before he can use the system optimally, and it is hard to maintain his high performance level due to the infrequent use of the system. Thus, the use of this system in the field is considered as no option due to its complexity. Another reason is that many errors are made by other members of the OT, due to use of verbal communication to convey the geo-spatial information, which result in the need to constantly update the map. For example, as shown Figure 3, the location of the CoPI team on the paper map was first drawn incorrectly, and then a correction was made. It was an error in distance of around 2.75 km. Furthermore, in some cases, the members of the OT are heavily occupied with their business and forget to relay any geo-spatial information to the plotter, which can result in outdated information shown in the situation map.

Figure 2. Problem with current information sharing several systems that were used by the plotter to support his tasks

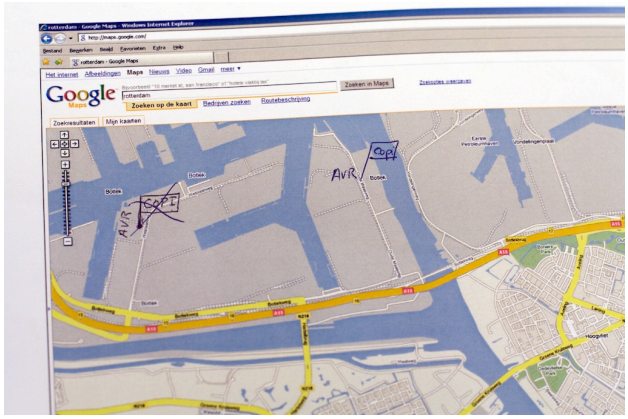


Figure 3. Error and correction on a paper map due to conveying geo-information over verbal communication

Overall, the current information sharing is inefficient due to the many chains of information processing. This results in information sharing delays, and even unshared situation maps among the CoPI team and the OT. As it is clear that there are problems with current information sharing, there is a need for collaborative mapping among these teams. We assume that by targeting the collaboration activities will result in a more effectively shared map than the support systems currently in use [3,4].

3. EXPERIMENT

Based on our observation at the Rotterdam-Rijnmond Safety Region, we are convinced that the distributed collaborative map has the potential to help this kind of user. By sharing information across organizations, both collaborating agencies in the field or in the command center can work jointly to overcome the system limitations. However, at this point, we still do not know how best to accomplish this goal. Thus we designed an experiment to get a better insight on the process of collaborative mapping. We were interested in gathering some observational data on how people collaborate in making a joint map. This first step can help us understand the basic characteristics of making a collaborative map. We would like to use the experimental results to explore potential problems in constructing joint maps.

3.1 Procedure

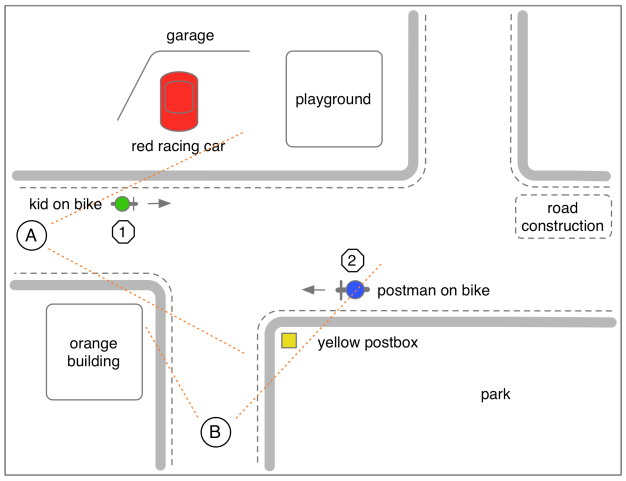
We constructed an experiment in which two persons collaboratively made a simple map together. Each experiment lasted between 30 to 40 minutes. In the first phase, the two participants were shown different photo series of 20 pictures

depicting an incident, where each picture was displayed for 5 seconds on the screen. Each photo series contained pictures taken from a different vantage point, thus some events were concealed from one of the participants, and vice versa. The photo series of the incident scenario were created by taking photographs of a miniature world populated with Playmobil toy sets. The Playmobil toys were chosen because they offered a good balance between simplicity and flexibility to be used for this purpose. After watching the photo series, in the second phase, the participants were asked to make their own sketch map of the depicted situation. Afterwards, as the third phase, they were asked to compare and discuss the differences in the maps they created individually, and then make a new joint map together.

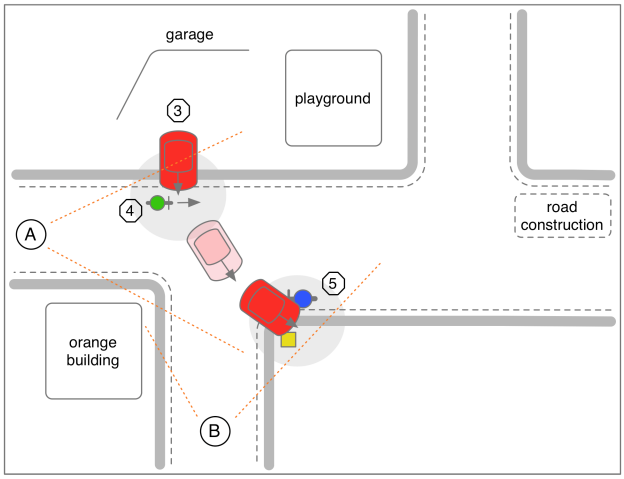
3.2 Scenario

The photo series used in the experiment describe an incident scenario in which the following events took place.

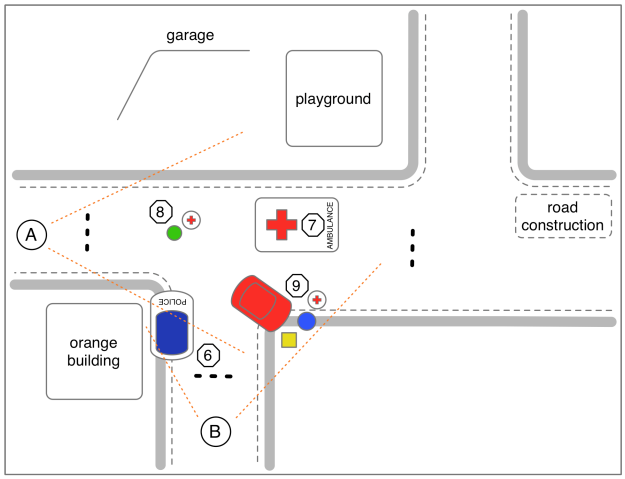
(1) A child on a bike was talking on his mobile phone without paying attention to the traffic ahead (2) At the same moment, across the street, a postman was riding his bike towards a yellow postbox (Figure 4a). (3) A red racing car abruptly hurtled out of a repair garage while being worked on by mechanics. (4) The car ran over the child, and injured him badly. (5) After hitting the child, the car continued cross the street, hit both the postman and the postbox, and then it stopped. (Figure 4b) (6) Shortly thereafter, the police arrived and closed down the area of the incident. (7) An ambulance with two paramedics arrived at the scene of the incident a while later. (8) One of the paramedics treated the child with the help of a bystander. (Figure 4c) (9) While the other paramedic provided first aid treatment to the postman with the help of another bystander. (10) The child was then transported by the ambulance to the nearest hospital. (11) The postman appeared to have no serious injuries, and did not require further treatment. (12) Finally, the police cleared the incident area and opened the street again to traffic. (Figure 4d)



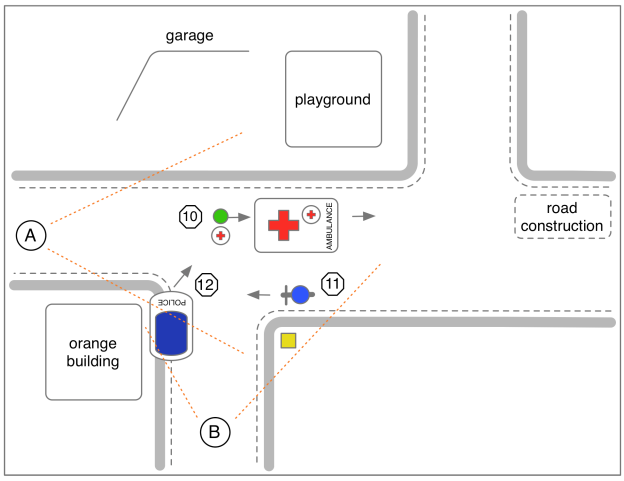
(a)



(b)



(c)



(d)

Figure 4. The overview of the incident scenario used in the experiment, (a) before the accident, (b) the accidents, (c) the response, and (d) the completion. A is the viewpoint of first participant, and B is the viewpoint of the second participant.

As mentioned earlier, the viewing angles were chosen in such a way, that some events were hidden or concealed from one of the participants. The goal was to stimulate the exchange of information, requiring them to collaborate in order to figure out

the complete scenario. Examples of these scenes can be found in three pairs of pictures below (Figure 5, 6, and 7).

first participant's point of view

second participant's point of view

Figure 5. Scene of red racing car hitting the child on a bike

In the scene of Figure 5, the first accident took place, where the red racing car hit the child. Both participants were able to see the accident, but the first participant had clearer view of the accident.

first participant's point of view

second participant's point of view

Figure 6. Scene of red racing car hitting the postman

The first participant could not see what happened after the car ran over the child, while the second participant clearly saw that the red car continued to hit the postman.

first participant's point of view

second participant's point of view

Figure 7. Scene of the child was carried into the ambulance

The first participant could not see what happened after the car ran over the child, while the second participant clearly saw that the red car continued to hit the postman.

The first participant could see that the child was loaded into the ambulance, but he could not see what happened to the postman. On the other hand, the second participant was not able to see that the child was taken by the ambulance, but he had a clear view of the postman being treated.

3.3 Participants

In this experiment, we had 10 participants, who were divided in five pairs. The participants sample consisted of researchers and master students at the Delft University of Technology.

3.4 Results

In the third phase of the experiment, the collaboration phase, the participants were instructed to compare their individual maps and, based on their discussion, to construct a new map out of their combined recollections. However, choosing which detailed steps they needed to follow in order to achieve that goal was left entirely to the participants. By observing the collaboration phase in the five sessions, we noticed a pattern of steps being used repeatedly:

1. Telling each other their account of the scenario by using the individual maps they created in order to figure out overlaps and differences in their stories:
   a. They start by stating many landmarks and stationary objects such as: garage, playground, orange building, construction road, postbox, cones, etc.
   b. Next was the orientation step, where the participants tried to figure out their relative positions on the map.
   c. Thereafter, they started to tell each other the events in chronological order.
2. Resolving differences and unclear facts.
3. Adding complementary information which were only known by one of the participants
4. Reaching agreement on the complementary information
5. Drawing the information of their combined accounts in a new map. Participants achieved that either by both drawing the map at the same time, or by allowing one of them to do the drawing while the other adding complementary information.

Table 1. List of activities

No	Activities
1	A kid on a bike was talking on his mobile phone
2	Across the street, a postman was riding his bike.
3	A red racing car abruptly hurtled out of a repair garage
4	The car ran over the kid, and injured him badly
5	The car crossed the street, hit the postman and the postbox
6	The police arrived and closed down the incident area
7	An ambulance with two paramedics arrived
8	One of the paramedics treated the kid
9	The other paramedic treated the postman
10	The kid was transported by the ambulance
11	Postman appeared to have no serious injuries
12	The police cleared the incident area and opened the street

Table 2. Completeness of the individual and joint maps

Acti-vities	Pair #1			Pair #1			Pair #3			Pair #4			Pair #5		
	a	b	ab	c	d	cd	e	f	ef	g	h	gh	i	j	ij
1			V			V			V			V			V
2			V			V			V			V			V
3			V			V			V			V			V
4			V			V			V			V			V
5			V			V			X			V			V
6			V			V			V			V			K
7			V			X			X			V			K
8			V			V			V			V			K
9			V			V						V			K
10			V			V			K			V			V
11			V			V						V			K
12			V			V						V			

In table 2 above, the white boxes are events that were not drawn on any of the maps while the grey boxes refer to activities that were drawn on an individual map. Activities that were drawn on the joint map are represented by V. The red boxes X represent two types of activities. Those of which were wrongly drawn on the joint map even though they did not occur in the incident scenario, and the activities that were known to one of the participants but became unclear or less certain as a result of the collaboration. Finally, the yellow boxes K refer to activities that took place in the scenario and were known by at least one of the participants, so they could have been on the joint map but they were not.

We measured the performance of the collaboration by comparing the individual maps to the joint map as summarized in Table 2. A positive performance was achieved when the participant filled each others missing information, and thereby correcting wrong facts (depicted by the green boxes). While the negative performance is when the joint map was worse or less complete than one of the individual maps (depicted by the yellow and the red boxes).

Four out of the five pairs were able to correctly identify their relative positions on the joint map. The process of understanding orientation and relative position was important and necessary to ensure a smooth collaboration. The one pair that failed to complete that step correctly (Pair #5), faced considerable confusion in the discussion process. This hindered their ability to identify certain events in the scenario. As a result, they failed to draw these known events on the map.

Two out of five pairs resulted in a positive performance, as shown in Table 2 (Pair #1 and #4). They managed to piece together all the events of the incident scenario and drew them on their joint map. In both cases, we observed certain collaboration elements that helped improve their performance. These elements include the participants' mechanism of constantly re-checking the story facts, their willingness to listen and to learn from each other, the equality of their standing during the discussion process, and whether they have a prior history of collaboration.

Below is a transcript of a conversation that took place during the experiment where the participants repeatedly re-check.

B: *"actually, I saw there was this car, but I thought it was going to run over the kid, but then afterwards I saw a picture of the postman also being run over …, with the letters on the ground"*

A: *"okay, the postman was also hit?"*

B: *"yea, I think so, yea"*

A was being informed that the

A: *"oh, hmm ..., interesting"* — postman was hit by the car, and clarifying this fact

"what I remember there was this bike, from my point of view, cycling here"

B: *"he eh, was it a kid?"*

A: *"it was a kid"*

B: *"yea I saw the kid too here on the bike"*

A: *"so it was a kid then on the bike, sure"*

B: *"I think so"* — In this discussion, participant A and B were verifying that the first victim was a child on a bike.

A: *"and then there's a car coming from the playground and that's run over the kid"*

B: *"well then the car runs over the both the kid and the postman"*

A: *"wow, that's impressive"* — The conclusion of the discussion

B: *"but the postman didn't go to the ambulance"*

A: *"okay"*

Collaboration provided negative performance in three out of five pairs (Pair #2, #3, and #5). From the observations. it seems that doubt about the observed events can cause hesitation in the collaboration process. In order to overcome the uncertainties, participants resort to adding extra information or omitting events they already had on their individual maps for the sake of reaching a consensus, as can be seen in the example below.

The red box X in pair #2 of Table 2, represent a faulty conclusion that resulted from their discussion. They concluded that there were two ambulances instead of one. The pair was indecisive in their discussion and took longer time to draw their joint map compared to the others. They often expressed their hesitation by using words such as 'maybe' and 'probably' in their conversation. Additionally, this was also caused by a mistake in one of the individual maps, where the ambulance was drawn in a wrong position. As a result, they were trying to overcome the confusion by proposing extra events that did not belong to the scenario. The conversation snippet below shows the part where an extra ambulance was added to the joint map.

B: *"you have the ambulance here, and I have the ambulance there"*

A: *"maybe I'm a little bit fuzzy with that"*

B: *"maybe there are two ambulances"*

Some collaboration biases could have been resulted of an unbalanced relationship between the participants, where a stronger personality or a more senior position can allow one participant to dominate the discussion process. These biases can cause some known facts to be discarded from the weaker participant. Examples of these biases are discussed one by one below.

The red boxes X in pair #3 of Table 2, represent the introduction of doubt over events which were believed for certain to be facts before the discussion. In this case, the second participant saw two accidents while the first participant, who seems more dominant, only saw one of the accidents. The following conversation shows the second participant, who was right at the beginning, being influenced by the first participant and then becoming unsure about the two accidents, and consequently left the unsure facts out of the joint map.

A: *"the green guy on the bicycle got run over by the red car coming from the garage, and the car then move crash into the thingy or something"*

B: *"I think it was a postbox and a postman"*

"I saw two accident actually, one it hit this guy on the bike in the middle of the street cross, then he hits the postman near the postbox"

A: *"Yea that could be something, I didn't see the postman getting hit, I thought he was still there at the end of the slideshow"*

B: *"okay"*

"okay, But we are sure that at least one accident"

"the second accident we don't know"

In the session of pair #5, a senior researcher was paired with a young master student. The student is represented in Table 1 as participant j. After viewing the photo series, she had almost all the events of the complete incident scenario drawn on her individual map. Unfortunately, the senior researcher (participant i) was uncertain of many facts. The discussion led to a worse joint map than the one originally drawn by the student. This was caused by her hesitation to speak up to the senior participant and being too polite to indicate that he was wrong. Therefore, many events in the student's account did not come out during the discussion and were not drawn on their joint map. These failures are represented by the yellow boxes in Table 2, pair #5.

4. GUIDELINES

Based on our field study observations and the laboratory experiment, we formulated our guidelines for collaborative situational mapping during the emergency response as follows:

1. The system should be easy to learn and easy to use, which is necessary to support any time critical operation under chaotic circumstances.
2. Time is a dimension that needs to be incorporated into the joint map. Both the chronological order of the events, as well as the time stamp indicating when it was added. All changes to the records should be kept as a history log that can be recalled when needed.
3. The orientation of the agents working in the field should be recorded together with their headings in order to help other collaborating parties understand their relative positions and their viewing direction.
4. All information entered to the system should be accompanied by some degree of certainty.
5. There should be a mechanism that evaluates the accuracy of the submitted information and protects information that is believed to be genuine from being overwritten.
6. The system should provide a simple mechanism to continuously recheck whether the joint map is accurate and up to date.

5. CONCLUSIONS

A collaborative joint map has the potential to support the disaster response team. However, the system should adhere to a specific set of requirements in order to take advantage of the submitted contributions. If not, then the system may result in the loss of invaluable data or introduce false events to the response team, and thereby hinder the rescue services rather than help them.

The requirements will need to be implemented in the system prototype, and tested in a subsequent experiment. This process will be repeated iteratively in order to refine the system.

The use of toys, Playmobil in our case, as quick prototyping material proved to be adequate in achieving our goal. It was possible to use the setup to easily simulate a modeled incident. On the other hand, since all Playmobil human pieces have a standard design with a smiling face, photos taken of the incident model may need further editing to convey more appropriate emotions.

6. ACKNOWLEDGMENTS

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