Position Tracking and GIS in Search and Rescue Operations

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Additional information is available at the end of the chapter

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Abstract

Geographical information systems can be useful in supporting an operational or situational picture in emergency situations. One particular use case is to keep track of moving personnel in the field. This has proven to be useful for safety (of rescue personnel), as well as for monitoring, planning and documentation of operations in the field. In this chapter, we define some concepts of tracking information, and tell the story how enthusiasts from the radio-amateur and red-cross communities developed and applied position tracking to search and rescue services in Norway. Based on years of experience from this work we discuss some issues related to how systems could deal with such spatiotemporal data in emergency and SAR situations.

Keywords: GPS tracking, SAR, GIS, volunteers, situational awareness, operational picture

1. Introduction

In emergency situations like *search and rescue* (SAR) operations or disaster response, it is essential that decision makers have correct and relevant information in a timely manner. SAR and other emergency management may involve a rather ad hoc organisation, and may depend on effort from various volunteers, amateurs and experts in different fields. Typically, different organisations (agencies) and different cultures are involved, using different tools and collaboration patterns. It may be challenging to establish a common understanding of the situation and to coordinate the effort in an efficient and effective manner while at the same time not compromising the safety of the involved personnel [1]. The information should therefore be correct, precise and easily understandable by the different actors. At the same time an information overload should be avoided.

In this context geographical information systems (GIS) are known to be useful in visualising information and presenting it on a digital map. This is essentially what has also been done manually before the digital age, using printed maps and drawing lines, areas and symbols on them. Visualisations on maps could be a part of a *common situational* or *operational picture*. Examples of geographical information in this context include positions and movements of resources working in the field, e.g., search teams, vehicles as well as observations of interest.

This chapter is a case study on how voluntary organisations in Norway (primarily the radio amateur association and the Red Cross) have explored using position tracking in land-based search and rescue operations. The materials are mostly the author's own experiences along with statements from participants as well as an interview. A system has been developed based on VHF radio communications and open source software. Since 2009, tracking has been used in several real incidents and some lessons were learnt from this experience. This story was earlier presented in [2].

We have observed that tracking and visualisation on maps reduces stress in the command centre or command post. It reduces the need for verbal communication with teams in the field. It can contribute to an improved situational awareness. It has been pointed out that that it addresses three issues: (1) the safety of search and rescue personnel, (2) need for coordinating resources and monitoring the operation and (3) post-operation analysis, planning and documentation. Offering a service like this may free operation commanders and SAR experts from technical tasks.

The rest of the chapter is structured as follows: Section 2 describes some background and related works and describes the role of volunteers and radio amateurs in particular in Norwegian land-based SAR. In Section 3 we describe some concepts of tracking as well as the design and implementation of a tracking system. This includes a tracking device and an application to process and display positions on digital maps. Then in Section 4 we describe experiences from using the system in real search and rescue operations. In Section 5 we look deeper into some lessons we have learned and issues we have encountered in the project like annotating the spatial information, connectivity, etc. In Section 6 we conclude.

2. Background

Information system support for emergency response [3] is an active field of research and development. Here, spatial data and geographical information systems (GIS) play an important role in helping increase the *situational awareness* [4, 5]. This includes location of incidents, affected areas or buildings, location of rescue teams, victims, shelters, etc.

A known issue is how to establish a common *situational* or *operational picture* [6–8]. In the literature, this concept has several definitions. The focus could be on creating a common understanding of the incident across multiple organisations and cultures participating in the decision making, or on the information systems supporting decision making. When focusing on information systems it is helpful to define and standardise a conceptual model for the information. In [9] the author develops such a model for dynamic, operational information from which database schemas can be derived. They distinguish between (1) *situational information* which is about the incident and its effect and (2) *operational information* which is about active responses, processes, people and organisations involved. They also distinguish between *static information* that exists prior to incidents like maps, roads and buildings and *dynamic information* which is produced during an incident. Dynamic operational information includes incidents, events, threatened areas, causalities, teams or vehicles. Some of the information can be *spatiotemporal*, i.e., it contains points in both spatial and temporal dimensions. For instance, spatial position of objects may change at particular time instants. Through spatiotemporal analysis one could derive trajectories of moving objects. A data model for trajectories in particular is explored, e.g., in [10].

2.1. Search and rescue

For search and rescue operations a number of information system tools exist for planning, coordination and decision support. The usefulness of GIS in SAR (as well as in emergency response in general) is well documented (see e.g. [11–13]). Advantages include having more updated maps, being able to easily connect between planned and documented efforts, to see areas that are searched or not searched and to integrate information from multiple sources. Another advantage which is mentioned in literature is the ability to keep track of rescuers which is the focus of this chapter.

GIS tools can also be used to apply search theory and statistical models to help planning the effort and increase the chances of success [14, 15]. One could use such tools [12, 16] to visualise the probability of finding the lost person, for example, distance circles may be drawn around the initial planning point (IPP) of the operation, which often is based on the last known position (LKP) of the missing person. [17] evaluates such probability models, more specifically where distance from the IPP determines the probability of success, where the terrain determines the probability (watershed model) and a combination of these two which seems to be a promising approach. The Bicycle Wheel Model [18] is a well-known application of such search theory in land-based SAR. It can easily be visualised and combined with tools to draw search areas, points or interest, to manage teams and missions, to write operation logs and to track the position and movements of search teams.

There are few commercially available land SAR tools and they are often not generally available since they often are designed for specific agencies or countries, are based on proprietary technology, etc. Examples include the Canadian SARPlan [15], the British SARMan [19], or Norwegian SARA [20] used by the Norwegian Joint Rescue Coordination Centre (JRCC).

The work described here focuses on one of the many parts of a GIS-based information system for SAR, namely position tracking of teams, vehicles, etc. Several commercial applications exist providing tracking or fleet maps, often proprietary and limited to single technologies like, e.g., Tetra. We are primarily using amateur radio APRS tracking. SARtrack in New Zealand

[21] has some similarities with our work, but some aspects of search planning are supported as well. Our system aims to be an extensible platform where such functionality may be added as well as alternative data sources. Our project is focused on open source software, it is web-based and open, while most other solutions require platform-specific programs to be installed on desktop or laptop computers.

2.2. Voluntary rescue services in Norway

Norwegian rescue services are organised as a cooperation between government agencies, voluntary organisations and private companies being able to contribute. Two Joint Rescue Coordination Centres (JRCC) has the overall responsibility for coordination of operations. Land-based SAR operations are usually led and coordinated by the Local Emergency Management Authority located at police districts. In a typical land-based SAR operation a temporary command centre (or command post) is established close to the location of the incident. The effort is coordinated by an operations leader which is a representative from the police force.

If approved by the JRCC voluntary personnel may be contacted and asked to help. Most voluntary organisations participating are members of the Norwegian Forum for Rescue Organisations (FORF), an umbrella organisation. Voluntary organisations may be specialists or experts on various fields. The largest and most used organisation is the Red Cross, which have a rather broad field of expertise. Other important organisations include the Norwegian People's Aid (general), the Rescue Dogs (search by dogs) or the Air Services (search by aircraft). One of the smaller organisations in FORF is the Norwegian Radio Relay League, NRRL (radio amateurs). They offer technical and communication support, for (1) SAR operations or (2) for larger emergencies where critical communication infrastructure is hit. Especially in the latter case, long-distance communication can be provided. Radio amateurs are enthusiasts that have access to a wide range of radio frequencies and technologies and can improvise to get messages through worldwide.

A more recent and successful contribution of radio amateurs to SAR is mobile phone localisation where a special task group can be assigned to interpret traffic data from cellphone networks in order to estimate the likely position of missing person. The last 10 years we have provided position tracking and geographical information systems. This is further described in the rest of this chapter.

It varies significantly which voluntary organisations are active in different police districts around the country. Volunteers may organise differently locally and have different focus in different areas. In addition different police districts may have different practice and focus. It is somewhat obvious the type SAR operations can be rather different in different parts of the country. Things are different in the largest cities than in small villages. In most police districts radio amateurs are seldom used, but in some they are used in a significant part of the SAR operations.

3. Position tracking and APRS

In this section concepts of tracking and tracking infrastructure are described. Based on these concepts we have implemented a portable tracker and a web application for displaying tracking information on electronic maps. It is based on Automatic Packet Reporting System (APRS) [22] which is an open standard used by radio amateurs worldwide. The adoption of APRS by voluntary rescue services in Norway does not exclude other technologies.

3.1. Tracking concepts

A *tracker* is a portable device that contains a GPS receiver and a transmitter (or transceiver) that can send its position through some infrastructure to an information system that can process and present the position on a map shown in command centres, etc. During operations a tracker is typically associated with a rescue team or vehicle carrying it. Trackers may be integrated into communication radios and use different technologies and infrastructures (e.g. APRS, AIS, Tetra, cellphone, etc.). Even a smartphone may be used as a tracker using the GPS and a proper app, though there may be issues like battery capacity or coverage. A *position report* from a tracker is associated with a time instant. The information system may present the tracker's position at a particular time or a series of such reports from the same tracker within a certain time-span as a *trail* (or *trajectory*).

3.2. APRS concepts

In the APRS protocol, *location items* can be either *stations* or *objects*. Stations have globally unique *identifiers* which typically are *radio callsigns*. Stations transmit *position reports* in order to update their positions or other associated information. A station typically corresponds to a physical tracker. In addition stations can report the position of *objects*. Since objects are *"owned"* by stations that report them, they do not need to have globally unique identifiers. Conceptually, this would imply existence dependency, but in the APRS protocol a station can in some cases take over the ownership of objects from other stations. This can be useful, e.g., when the station that generated it in the first place stops operating and we still need to keep track of the object.

A location item has a (possibly moving) position and is associated with a *symbol* that is sent with position reports. A symbol can be used to indicate what type of item it is or what mission it is assigned, e.g., car, aircraft, boat, rescue-team, etc. A symbol is typically used to select an *icon* when plotting the item on the map.

A position report is associated with time either by *timestamping* it at the source or timestamping it when received. A *trail* for a given location item is an ordered list (by time) of reports within a given timespan before the last reported position. In a real-time view this means showing the movements of stations (as lines and points on the map) some minutes back in time.

3.3. Tracking infrastructure

A tracking system needs an infrastructure to convey and process the stream of information between trackers and the applications where the information is presented. This is also the case for APRS which use AXE.25 [23] data packets to send reports over a radio. It uses a single VHF channel and a rather narrow band form of modulation (1200 baud audio frequency shift keying). The *APRS protocol* [24] defines formats for position reports as well as short text messages, telemetry, weather reports, etc. Though it is criticised for being aged and not optimal, it is free to use, an open standard, well tested, widely deployed in the radio amateur community and used on a daily basis. APRS devices are affordable, or not too hard to construct.

The infrastructure consists of several components (see **Figure 1**). Trackers broadcast their information. This is collected by internet gateways (or directly by client apps), possibly after being retransmitted by digital repeaters (digipeaters) to extend the coverage area. The APRS Internet Service (APRS-IS) is a worldwide network of servers that can interconnect the gateways and provide data to applications. The range of repeaters or gateways depends on the topography, antenna height, etc. A range of 50 km is not unusual. The fixed infrastructure can be extended by deploying mobile repeaters or gateways. Data in transit are not encrypted.

3.4. Implementing tracking

Traditionally, radio-amateurs contribute to voluntary search and rescue services by providing communication services. Tracking is an extension of this service. In a more technical sense the implementation of tracking can be said to be twofold given that much of the fixed infrastructure already existed: (1) Developing a tracker and (2) developing a web-based application for presenting information on electronic maps.

Though some APRS trackers were available commercially, they were often not complete units designed for SAR operations. In 2008, the radio amateur group in Tromsø therefore decided to design and produce an affordable, compact, waterproof, handheld-size tracker that was easy to operate and had battery capacity for at least 24 hours operation. It was a complete, self-contained unit. The tracker was named *"Polaric Tracker"* and prototyping took place in 2008 and 2009. Already in this prototyping process trackers were used in real SAR missions (see Section 4) which gave us valuable experience and ideas. Later, some other, handheld trackers have become commercially available, somewhat smaller in size, but with less transmitter power and somewhat shorter range. **Figure 2** shows a Polaric Tracker and a SainSonic AP 510 (commercial) tracker.

The other enabling technology development is the "*map server*" application named "*Polaric Server*". It was based on well-known Open Source software and designed to run on small portable servers to be brought to the command post as well as running as a online service on

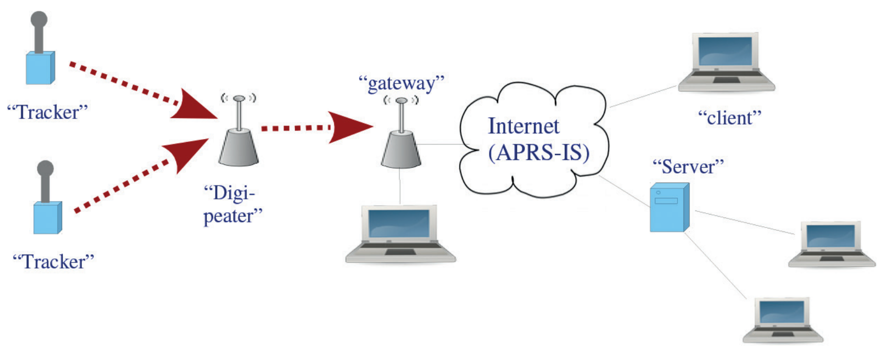

Figure 1. APRS infrastructure.

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Figure 2. A Polaric Tracker (right side) and a more recent commercial tracker (left side).

the internet. It is essentially a GIS application which can be used to display position of objects on digital maps (based on received APRS reports) and update them in real time. End users only need a standard web-browser. The application supports manually annotating position objects on the server (with proper icons and labels), it supports tagging and filtering to deal with information overload, it can combine various data sources and it supports storing and querying past data in a spatiotemporal database.

In December 2009 the Norwegian Mapping Authority (Kartverket) started to offer geographical data and web services (WMS) to the general public, to enable the use of maps in various applications. This enabled us to immediately offer an open online service with quality maps. Keeping our service (mostly) open to the public was also believed to encourage testing and development as well as recruitment of interested people to the radio-amateur and voluntary rescue communities.

The application has been deployed in several instances. *Aprs.no* is the official online tracking service by the Norwegian Radio Relay League. The Norwegian Red Cross has been offering a similar service for their APRS tracking system and is now developing a new system[1] which builds on some of the ideas and experiences from the project described here.

4. Use of tracking in SAR

During almost 10 years of operation, the tracking system described in this chapter has been employed in a variety of SAR operations, exercises, sports events, etc. It started in 2009 in the Tromsø-area when the *Polaric Tracker* prototypes were made. The concept was tested in an exercise with the Red Cross and soon after, in February 2009 there was a large search for a person missing from a fishing boat near Vannøya in Karlsøy in Tromsø. Several voluntary

[1]This has been named *SARSys*. As this chapter is being written, it is work-in-progress and little published information is available. It will be designed to use tracking data from the Tetra network used by most emergency services in Norway.

organisations were called out to help. The first day there was an aircraft search at sea and trackers were placed in aircrafts to follow their location.

The next day it was decided to perform a search along shores. A base was established at Kristoffervalen near the search area. A total of 11 trackers were deployed on search teams from the Red Cross, Norwegian People's Aid, Civil Defence as well as boats from the sea scout group. A portable APRS repeater, internet gateway and map server was deployed near the base. A video projector was used to display the operational picture (see **Figure 3**).

After this incident, tracking has been used for a number of operations around the country. As also pointed out by others (see e.g. [13]) we observe that tracking work best for long search operations which can last for several days and cover larger areas. Here, multiple SAR teams operate at the same time with some coordination from a command centre and there is some time to organise. This is in some cases searches for presumed dead persons which are difficult to find. There are also examples of persons that have been lost in the mountains, search for missing people with dementia as well as search for suicidal persons. Though many searches have been in the wilderness, some searches have actually been performed in or near a city.

Voluntary organisations are sometimes invited to contribute in larger national and international crisis exercises, in some cases with tracking. An example is Barents Rescue 2013 [25] where tracking was used on Norwegian, Swedish, Finnish and Russian rescue units, boats and helicopters. In addition, tracking is popular in large sports events, like, e.g., marathon, ski or bicycle races which can be seen as relevant training, especially when the event is spanning large distances. It is useful to keep track of where the lead is, as well as where ambulances and other mobile support functions are moving.

In 2009 and the following, most of the tracking activities were in the Tromsø area in the Northern Norway. In 2010, there were about 10 SAR operations, most of them in Tromsø, but if we also count exercises and sports events the number is closer to 25. In 2017 NRRL was involved in about 25 SAR operations, most of them in the Oslo area.

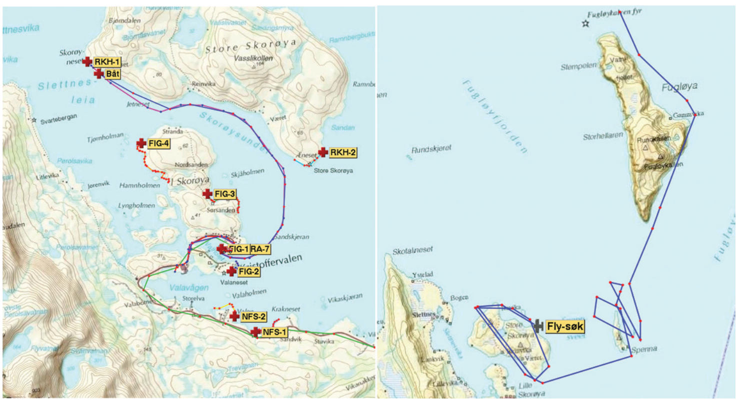

Figure 3. Operational picture of shore search and aircraft search Vannøya, February 2009.

4.1. Tasks and roles during operations

There are some tasks and roles that are typical for land-based SAR operations where trackers are used. When a person is reported missing, the police collect intelligence and at some stage it is decided to call out SAR personnel. A command post is established, often close to the incident and search teams are assigned areas to search. If possible, each search team will be assigned a tracker when going out. Also, vehicles used for transport or search like cars, ATVs, snowmobiles, helicopters, etc. may have trackers.

Operating the tracking information system can be a specific task or role in the command and control centre. The operator should keep a record of each tracker's callsign and what mission it is assigned to. This information is used to give trackers meaningful labels and icons when they appear on the map. Unnecessary items may also be hidden. The operator may present a relevant operation picture to operation commanders using a large screen or video-projector or the operation commanders may be given access to the application on their own tablets or PCs. Also the JRCC or the Local Emergency Management Authority may use the web-application to follow the operation or get reports with screenshots. The operator (or team of operators) may also take care of other communication tasks or technical support.

In addition to tracker's positions findings or other points of interest can be marked on the map. These can be put in manually by the operator or tracker can send such points as APRS objects (see Section 3.2). The annotation and editing task as well as post-operation documentation is often delegated to volunteers located at home. Having an online server-based mapping application that can be operated over the internet or radio makes such delegation easy. Operation commanders, other personnel in the command centre or even teams working in the field may also see the online map using their personal computers or tablets.

4.2. Documentation and historical data

After the operation is ended or ended for the day, an important task is to document what has happened. This includes information on what areas has been searched, when and by whom. The ability to query and visualise past search activity addresses this need and is useful in the planning of the next day. The police may want to show to close relatives of the missing person what has been done and what areas have been searched. It is also not unusual to invite close relatives to the command post during the operation where they can see the real-time map as well. In addition to online tracking, data could be downloaded from portable GPS devices to provide more detailed information. Having an application where data are collected and stored in a spatiotemporal database in real-time, we can do a historical search at any time during the operation. This can be an additional tool when monitoring the progress of the operation.

In an early phase this was improvised by using external APRS services that store data over some time. In 2012, after requests from the police, a module for Polaric Server for storage and retrieval using a spatiotemporal database was made. **Figure 4** shows an example of a full day search (10 search teams) on the left side and 1 day search by a single aircraft at the right side. This may look a bit chaotic, but keep in mind that we may narrow the search to specific missions or timespans and we may export the result in a open format (GPX) to be further analysed in other tools.

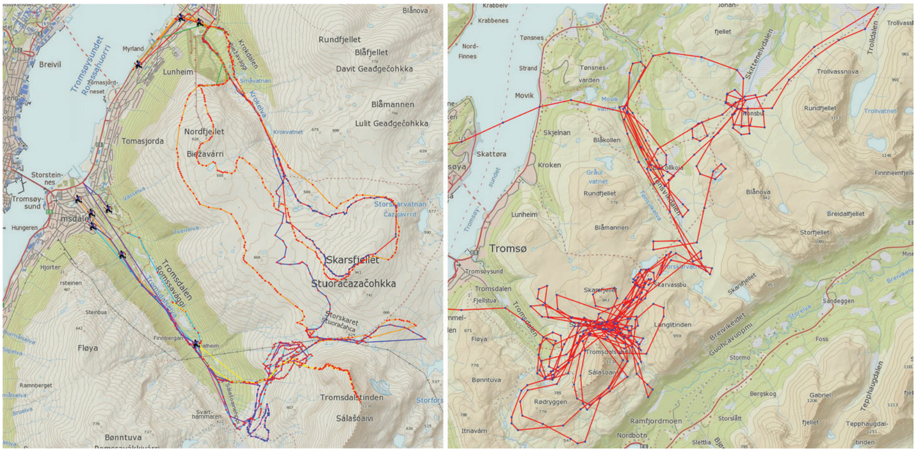

Figure 4. Historical records of a day of mountain-search near Tromsø in 2012.

One of the lessons learned from using this is that we should always take note of the missions of the individual search teams, the callsign of their trackers and the starting time and ending time of the missions. This information is collected when the team is assigned a mission and a tracker. Having this information we can in principle look any mission up in the database at any time later. For privacy reasons we may however want to limit the scope of the database.

4.3. Case materials

Since GIS and tracking is much about visualisation, it is useful to illustrate by showing some selected snapshots from real SAR operations. It is beyond the scope of this chapter to describe all incidents. Some details are also left out.

Figure 5 shows a real-time view (with trails) of a search in Lavangsdalen near Tromsø in 2012. At this particular moment there were 10 active teams and two observations (points of interest) marked as objects by the *"RK lag 1"* (Red Cross Team 1) tracker. The car of the missing person was found near the road (the cluster of trackers on the map) and this was the last observed position and the location of the command post. In addition, some belongings of the person were found in the stream up in the hillside. The search was therefore focused around the stream up to the mountaintops as well as near the road itself. The operation went on for several days and there were search teams from the police, Red Cross, Norwegian People's aid and Rescue Dogs. In addition a voluntary aircraft and a helicopter were employed. The person was not found and this has later become an unsolved murder case.

Figure 6 shows two pictures from a search for a missing person hiking in the mountains near Tromsø in 2012. The left image is a real-time view (with trails) shortly after the search was started showing eight active teams. The right image shows a historical search (for documentation)

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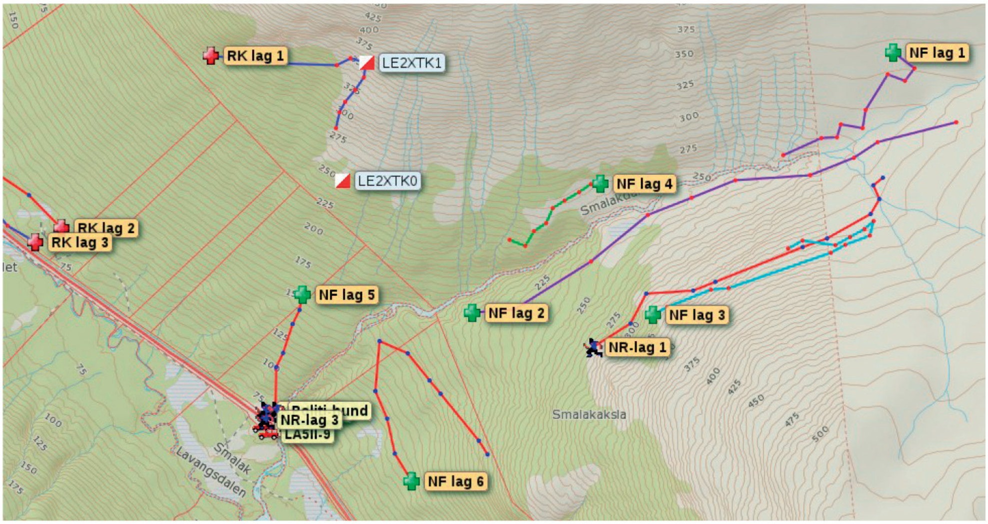

Figure 5. Search in Lavangsdalen near Tromsø in 2012.

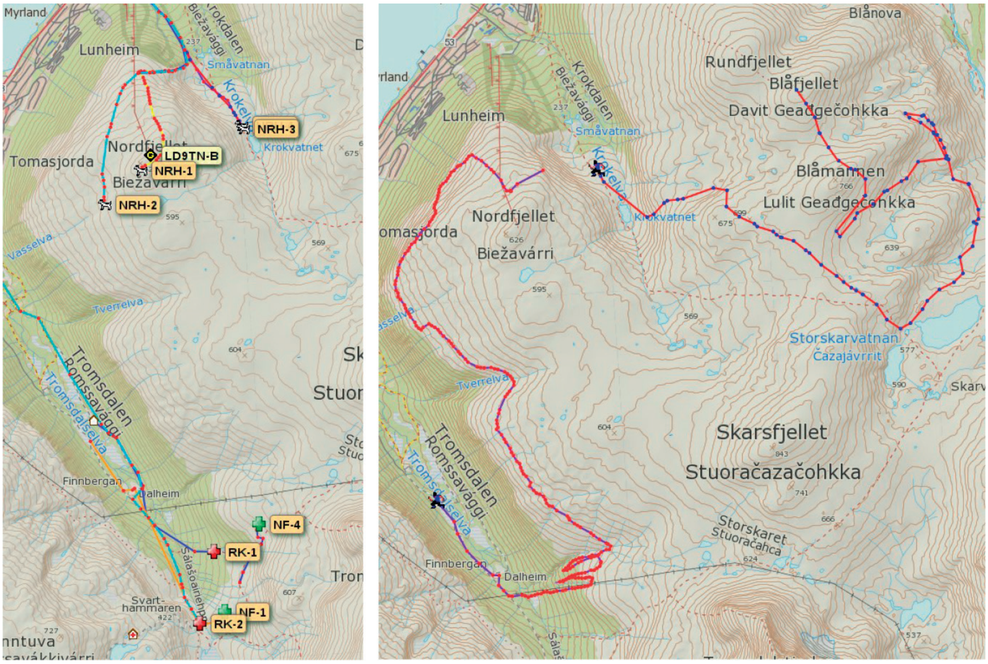

Figure 6. Mountain search near Tromsø in 2012.

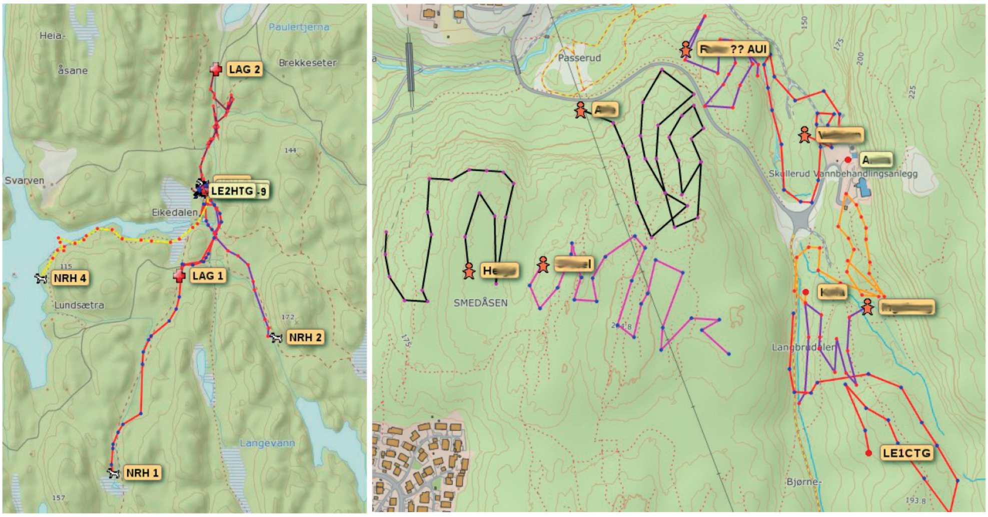

Figure 7. Search operations in Larvik 2012 and Oslo 2018.

with a selection of the effort of two of the teams through 1 day work. There were large uncertainties wrt the location of the missing person and the search went on for several days over a large area. Aircraft searches were performed and many voluntary people searched large areas without success. Due to the complexity of this operation it became clear that we needed to implement historical search (see Section 4.5).

The left image of **Figure 7** is rather self-explanatory. It shows a search operation near Larvik in 2012. It is a real-time view (with trails) of 5 active teams with trails. It clearly shows how the teams start from an initial planning point (IPP) and search along paths where the missing person most likely could have walked.

The SAR group of NRRL (radio amateurs) in Oslo is currently the most active group with 20 active persons. They cover two police districts including central Oslo and provide tracking, common operation picture, and other technical support like power and internet to the mobile command post. The right picture of **Figure 7** shows a typical operation in Oslo in January 2018 with a real-time view (with trails). Names of search team leaders are blurred. The search assignments and the actual search patterns can be clearly seen on the map. The missing person was last seen in the residential areas and a possible observation the night before search started, the person was walking toward the forest. A search close to this IPP was performed with nine teams from the Norwegian Rescue Dogs and the person was found and the position marked on the map.

NRRL provided trackers to search teams, two persons were helping at the command post and one person operating the map at home. A PC was placed at the command post to see the progress of the search. After the operation, historical trails were generated in an open (GPX) format and sent to the local police central along with logs from GPS units.

5. Lessons learned

In this section we look into some lessons learned and issues for further research and development encountered in this project. This includes combining and refining data. First, the development process described here has mostly been voluntary work and innovation is typically a result of participation in voluntary rescue services where radio-amateurs have traditionally contributed with communication support. Advanced information system support is a more recent contribution.

A command centre of a large operation typically uses experts in various fields. Communication and information management and GIS in particular may be regarded as a field of expertise, so a role that could be useful in a command centre is the role of *information manager.*

5.1. The benefits of position tracking

We have observed some immediate effects of using tracking in SAR operations. This is also clearly formulated in statements from police officers leading SAR operations. According to one of these statements[2] the usefulness of such a tracking system is due to three factors:

1. The safety of personnel participating in search and rescue operations in the field.
2. Effective and efficient monitoring of the operations and coordination of resources.
3. Documentation of the operation after it has finished for the day. Planning for next day of operations.

The first two aspects are about *real-time* information, i.e., the focus is the *current* situation or recent events. To elaborate on the second aspect; being able to visualise the situation and its development has proven to reduce the need for other (verbal) communication and reduces the level of stress in the command and control centre. For instance, a quick look at the map can reveal that a search team is about to complete its mission and would soon need transport (from a location). Queries can be made if progress unexpectedly seems to have stopped. Warnings can be given if personnel accidentally move into dangerous areas. Some decisions can be made in advance, increasing the efficiency of the operation. Hence it can make sense to use the term *tactical picture*, in particular if the advance planning of operation can be visualised. Informants also emphasise the need for coordination in the rescue phase, and the usefulness of quickly locating the person to be rescued and resources nearby:

> *"When the finding was reported by one of the search teams, we could immediately locate its position, we marked it on a map on an ipad and gave to the police officer in charge".*

The third aspect is further described in Section 4.5. It is about past events and is useful in tactical and strategic decisions (planning), in post-operation reporting and de-briefing. It allows us to see what areas have been searched during the day. In contrast to the two first aspects, data need to be stored and properly indexed in a *spatiotemporal database* to facilitate queries on what happened in a particular area in a particular time frame.

[2]A note by Anne Sjøli in Troms Police District to the Tromsø radio amateur group, dated February 23, 2009.

5.2. Refining data: annotating spatial information

An essential feature of the system described here is the ability to *annotate* position items by the use of *descriptive labels* (in APRS applications such labels are often termed aliases or *tactical callsigns)*. In the AIS system a vessel always has an MMSI identifier, but can also have a callsign and a name. Usually the name is used for labels since it usually is easiest to recognise by humans. A callsign identifies a *tracker*, not the mission and is by itself not very informative. Therefore, some meaning needs to be added to help seeing what a tracker represents. A single tracker is assigned to different people, teams and vehicles over time, which again are assigned to different *missions* over time. If the *label* and the *icon* on the map instead of just showing the identity of the tracker, tell something about *who* carries it, its *mission* and possibly what type of vehicle it is, it is obviously more informative. However, some care should be taken not to overflow the map with information. The descriptive labels should be short. It is possible to add longer texts that are shown when the user clicks on the icon on the map.

A good choice of icons may also make the picture clearer and we may benefit from standardisation of icons. In the APRS protocol (see Section 3), each position report carries a *symbol tag* which is meant to indicate a *type* of vehicle or mission. The application will select a proper icon based on this tag. However, it may be impractical to update the symbol setting in each tracker each time it is assigned to a new mission. Therefore we allow the server operator to change the icon as well, for example, to use a red cross icon when a tracker is assigned to a red cross team. It may also be more convenient to enter this extra information into the server than letting each tracker send it. Trackers don't have alphanumeric keyboards and it is more efficient to assign the task to one person keeping a record of all trackers involved.

In addition to icons and aliases, newer versions of the software allow the operator to annotate position items with *tags* that are essentially freely chosen keywords. For example, items associated with SAR operations may be tagged *"SAR"*. Tags can be used when searching the database of items. Tags are also used to determine how items are to be displayed on the map, for example, if the label is visible, if the trail is visible, how long it is (time-span), what icon to use, and what colours and label styles to use. It can also be used to hide items and determine who are authorised to see them. This is configured as a *filter-specifications* created by the system administrator as *rule-bases*. The user can select from a menu of predefined set of filters to choose what items to display and how. This is an effective tool to address the problem of information overload. Tags can also be added automatically to position items by rules based on more technical information like callsign, symbol from tracker, channel or even other tags.

These observations indicate that a possible topic for further research is *semantic annotation*, which may be especially relevant when data from different sources are to be combined and linked. We could benefit from relating tracking information to conceptual models like [9] and look closer into ontologies and semantic technology [26, 27]. Future research may also explore more advanced spatial or spatiotemporal data analysis and even machine learning techniques to help analysing data and determine what moving items represent.

5.3. Combining data from multiple sources

The system described here is extensible and could potentially *combine* data from a range of different sources. Some types of data sources are: (1) *Static geographical data from authoritative public sources* (typically maps and GIS application data), (2), *other public open data* (mostly static), for example, about weather conditions, road disruptions, web-cameras along the roads, information about hospitals, shelters, etc., (3) *static geographical data produced by crowdsourcing, e.g.*, OpenStreetMap [28], (4) *data from different position tracking systems* like AIS, smartphone apps, or various commercial systems and (5) *data entered by the users of the system* as the information is discovered, either directly to a web-application, via smartphone apps. Our current online service uses several of these, including AIS data from the Norwegian Marine Authority.

5.4. Summary and discussion

It is known that Geographical Information systems can improve situational awareness in crisis management. Tracking positions of search and rescue personnel, vehicles and other points of interest is no exception. Visualising the situation on a map what is going on is more concise and clear than telling the story just with words. Having such a map reduces the stress at the command post and reduces the need for other radio communications. Important benefits are (1) the safety of SAR personnel, (2) more effective and efficient coordination of resources and (3) available information for post-operation analysis and documentation. We have seen this in a number of real SAR operations.

This chapter describes the implementation and use of a tracking system based on APRS, mostly provided by radio amateurs. This has strengths and weaknesses and some challenges clearly exist:

5.4.1. Strengths

A main strength of the tracking system described is that it is an open system. It is based on open source software, open public data and open protocols. With an open protocol like APRS, a number of alternative client applications are available, you are not tied to a particular vendor or product. This also makes it rather flexible. If we operate from a command post without broadband internet, it can be run on a local portable computer with the Polaric Server software or another APRS compatible program connected to appropriate radio equipment.

In contrast, many fleetmap or tracking systems exist though most of them are rather proprietary and limited to particular products, or they require platform-specific programs to be installed on a PC. Such systems are often limited to particular sectors and historically interoperability between systems has been limited. Our system is easily accessible through the web for anyone who are interested. Normally it is open for all to see, but during sensitive SAR operations information can be hidden for other than logged-in users. This was implemented after a specific incident where journalists published links to the system during a operation [2].

It is low cost and based on voluntary work. And since it is used and tested by enthusiasts on a daily basis, there is a high probability that serious problems are discovered and fixed quickly.

Involving radio-amateurs with expertise on radio-propagation and powerful transmitters, let us cover areas not covered by cellphone networks or other fixed public networks. Radio coverage can also easily be extended to remote areas using mobile equipment and the system can be operated remotely.

5.4.2. Weaknesses

Some of the main strengths are also the main weaknesses. The system is vulnerable since it depends on the time, enthusiasm and advanced technical knowledge of very few volunteers to develop and run it. This is the main weakness, challenge and barrier of implementation.

The access to public or private funding is very limited. We got funding for developing the Polaric Tracker, but we have failed to get funding for further developing the software. It is also difficult to recruit software developers with the proper skills. Therefore, the project moves slowly and essential functionality is not implemented or bugs are not fixed due to lack of resources.

NRRL is a small organisation with ageing members. A fraction of the members are interested in SAR, so the service is offered in parts of the country. Currently the activity is mostly in the capital, Oslo. Even if the system is easy to operate, it is technically complex. The system main operators should have some technical knowledge and understanding how it works. Therefore some organisation and education is necessary.

Technically, APRS is rather old and not optimal and eventually more efficient technologies will take over.

5.4.3. Other issues

To reach its full potential our system needs access to open public data, most importantly to map data through web services. Not all countries allow such access to map data to the general public and Norway started opening up Web Map Services (WMS) in 2009. Free or commercial alternatives like OpenStreetMap or Google Maps do not provide sufficient detail in remote areas though valuable in more populated areas.

The *precision* of tracking points from cheap GPS units seems to be acceptable in the spatial dimensions. It is usually within a few meters. The challenge is however with the *temporal* dimension. An APRS channel is very narrow band and is shared among many devices. Therefore it has a very limited capacity. Furthermore, transmissions may be lost due to weak signals, collisions, etc. APRS trackers implement an adaptive algorithm to decide how often to send, that takes speed and direction changes into consideration.

Coverage in remote areas can be better than with tracking systems using the cellular networks at the cost of a lower bandwidth. We have experimented with using a smartphone app as a tracker. This could be an alternative in urban areas, but we need to be aware of the drain on the battery. Using a satellite-based tracking system offers an almost total coverage in remote areas, but is expensive to use and may offer less bandwidth.

6. Conclusions

Geographical information systems (GIS) play an important role in crisis management in that it contributes to situational awareness by visualising spatial information on maps. A particular application of this is real-time GPS tracking of search and rescue (SAR) personnel, vehicles, observed points of interest, etc. This chapter tells the story how volunteers in SAR operations in Norway, in particular radio amateurs, contribute to situational awareness by providing services for position tracking based on open standards, open hardware and open source software. This took off in Tromsø 2009 with open public map data, a portable tracker and a web-based GIS application to visualise moving objects on maps.

The benefits of tracking is threefold: first, a main motivation is safety for the search and rescue personnel which is better if operation commanders can monitor where they are, second it has proved to be useful in monitoring and coordinating operation, especially in operations in larger areas where many different resources need to be coordinated, like search teams, boats, aircrafts, cars, snowmobiles, etc., or when initiating the rescue phase after locating the missing person. Third, we have after requests from operation leaders implemented a database of historical data to facilitate documentation and analysis after operations are ended; typically for reporting and de-briefing. Especially in the real-time views we observe how important it can be to annotate and filter the information properly, for example, by using informative labels and icons.

An open system has some advantages w.r.t. flexibility and interoperability. The main weakness, challenge and barrier of implementation seem to be that system is that it depends on the time, enthusiasm and advanced technical knowledge of very few volunteers to develop and run it. That it is voluntary work is both a strength and a possible weakness.

There are many cases for further research and development. In general tracking is part of the information system used to support operational and tactical decisions. We envisage the integration of a larger set of different data sources, crowdsourcing, and interoperability between different systems. To support this we can look closer into data models for SAR use, semantic annotation, etc. Further research on information systems for emergency management could look into several problems, for example, how they could adapt to varying connectivity, or varying quality of data (e.g. reliability), for example, by assessing the quality of combined data presented and informing the user what he/she can expect.

Conflicts of interest

The author is a radio amateur and have been involved part in voluntary rescue services in Norway. I have participated in developing Polaric Tracker which is described in this text and is the main author of Polaric Server which is described in this text. I am also responsible for the mentioned online service aprs.no.

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