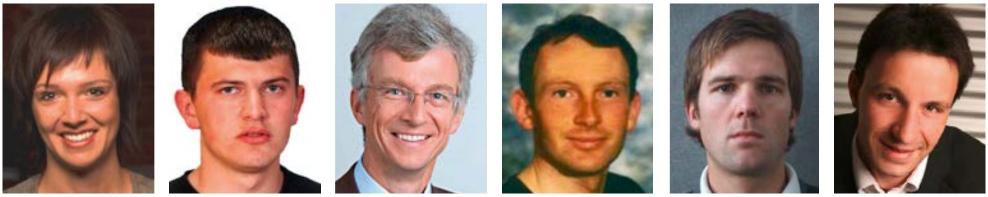
The Race Against Time In Alpine Regions By Satellite-Based Technologies



Claudia Fösleitner, Driton Kuçi, Bernhard Hofmann-Wellenhof, Hans-Peter Ranner, Rainer Prüller and Klaus Aichhorn

Abstract

More than 300 persons per year die in the Austrian Alps. The increasing skiing, hiking, and climbing tourism implies a variety of high risks. In case of accidents, the race against time is crucial and needs to be supported as much as possible.
Integrating positioning, navigation, geoinformation, and communication techniques, an innovative system has been developed and is ready for use to improve the assistance and coordination of rescue forces in case of Alpine accidents such as avalanches and hiking or climbing accidents.

Keywords: Search and rescue, GNSS, Geographic information systems, Communication

Kurzfassung

In den Österreichischen Alpen verunglücken jährlich mehr als 300 Menschen tödlich. Der steigende Wander-, Kletter- und Schitourentourismus birgt viele unterschiedliche Gefahren. Bei Alpinunfällen ist der Wettlauf gegen die Zeit kritisch und muss daher so weit wie möglich unterstützt werden.
Durch die Integration der Technologien Positionierung, Navigation, Geoinformation und Kommunikation wurde ein innovatives Gesamtsystem entwickelt, das die Unterstützung und Koordination der Rettungskräfte bei Unfällen im alpinen Raum – wie zum Beispiel Lawinenabgängen, Wander- oder Kletterunfällen – erheblich verbessert.

Schlüsselwörter: Such- und Rettungseinsatz, GNSS, Geografische Informationssysteme, Kommunikation

1. Introduction

Based on a project named SARONTAR (Search And Rescue Optimization by satellite Navigation Technologies in Alpine Regions), first a functional demonstrator has been developed comprising the system components mobile terminal, mission control center, and communication link [1] as shown in Fig. 1. Then the focus was put on achieving the technology readiness level of a mission-proved prototype. The system consists of three segments: a portable mission control center, a regional data center and several mobile terminals. The mission control center assists the leadership to obtain a visual overview of the current situation. This helps to analyze the situation rapidly and to forward precise instructions to the search and rescue teams. At the regional data center, the entire data set is stored, which enables a post-mission reconstruction and documentation of the operation. The search and rescue teams are supported by mobile terminals, which operate as combined communication and navigation tools. These provide current mission-related information and positioning data by Global Navigation Satellite Systems (GNSS). Due to the rough climatic conditions in the Alps, rugged hardware components as well as sophisticated software design are necessary to fulfill the demanding user requirements, especially for the mobile system components. The mobile terminals and the portable mission control center are connected to the regional data center by a hybrid communication link. Considering possible terrestrial communication outages, satellite communication systems are also utilized.

The chosen open architecture allows for the extension of further rescue organizations, e.g., air emergency and fire brigades, and provides the basis for a regional disaster management system in the near future.

2. Components of the System

2.1 Mobile Terminal

The search and rescue teams are supported by mobile terminals. Generally, positioning data is provided by Global Navigation Satellite Systems [2], at present GPS (Global Positioning System)

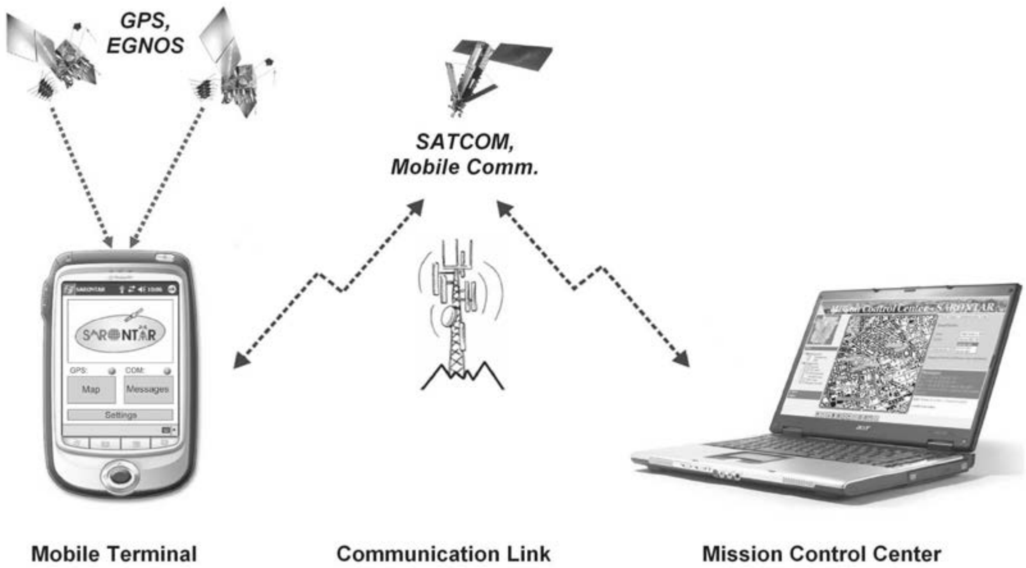


Fig. 1: System architecture of the functional demonstrator with the components mobile terminal, communication link, and mission control center

and EGNOS (European Geostationary Navigation Overlay Service). Positioning data including time stamps are transmitted automatically to the mission control center in constant intervals; however, due to the challenging Alpine topography and vegetation, signal obstructions are possible. This effect may cause short-time outages of positioning data. Due to the rough climatic conditions in the Alps, rugged hardware components and sophisticated user interface design are necessary to fulfill the demanding user requirements [3]. Ease of use and range of function as well as clear arrangement and information content, have been taken into account within software development.

The main window of the graphical user interface consists of two red/green signal indicators for navigation and communication, a message protocol list box and three buttons for displaying a map, sending messages and setting various system parameters, see Fig. 2. An extra large button design with sufficient displacement is required to enable easy handling even when using gloves in winter season. With the button "Map" a mobile GIS (Geographic Information System) is invoked. The current position and the track of the mobile team are mapped on an Austrian Map raster image. Additionally, mission-related information received from the control center can be displayed, including search areas and points of interests (POIs). In case of search and rescue applications, POIs include, e.g., helicopter landing sites, meeting points, and locations of lost equipment or injured persons. The button "Mes-

Fig. 2: User interface for the mobile search and rescue teams

sages" calls a dialog window, where different predefined messages can be selected and sent to the control center, e.g., an SOS alarm message. Furthermore, the user is able to type additional keywords on a sophisticated touch screen keyboard. The message including keywords, time stamp and positioning data is transmitted to the mission control center via the communication link. When receiving a message from the mission control center, the user will be informed by an acoustic signal. A message box including text message and time stamp is invoked. In this case, the user is immediately prompted to return "ok", "later" or "negative". The protocol on the main window allows an overview of all sent and received messages. In summary, the search and rescue teams in Alpine regions are supported by the mobile terminals, providing positioning data, a continuous communication link and current mission-related geoinformation.

After several experiences in reality, some additional features were formulated by the rescue teams, e.g., replacing the Personal Digital Assistant (PDA) by a smartphone. Therefore, further investigations have been performed mainly in 2010/11. Now each mobile team is equipped with two mobile devices, a smartphone (on which the application is installed and runs), and a satellite handheld mobile. The smartphone supports touch-screen, Bluetooth technology, data transfer (e.g., GPRS or UMTS service), virtual serial ports, different display orientation (landscape and portrait). In addition, it is equipped with a GPS receiver and a camera. The smartphone runs in Windows Mobile OS. The satellite handheld mobile is used as a gateway for the smartphone to connect to the server if the connection cannot be established via the Mobile Network (MN). This happens in areas being not covered by the MN or due to possible disaster cases where the MN does not work at all. The application of mobile terminal attempts to connect with the server via MN and tries to avoid the connection via the satellite mobile because of the high costs and the battery life of both devices since the Bluetooth radio has to be used as well.

The star topology is used where the server is in the center and all other clients (mobile terminals and mission control center) around it. Each connection is totally independent from the others. In cases where a specific connection is dropped only that specific team loses the connection with the server, the others remain connected. Communication between the mobile terminals and the mission control center is based on messages and is realized only through the server. These messages are used to register all teams as active, send the current position of the team, send and receive text messages, inform the teams about POIs (meeting place, injured people found, helicopter landing place, etc.) as well as any search sector (area that a team has to cover by its search). For terminating the application, a special message is sent in order to inform the mission control center that the application is voluntarily terminated. Some of these messages are sent automatically and periodically and the teams do not have to pay any attention to them. To detect errors occurred in the message, the XOR checksum (two-character hexadecimal number) added at the end of each message is used. There is no error correction algorithm implemented, thus, errors can only be detected but not corrected. The whole communication traffic between the teams during the intervention is stored in a database being located in the server computer. When the connection with the server is operable, either via the mobile network or via the satellite mobile, every message is sent immediately upon creation; however, if the connection is lost for any reason, the messages are saved in appropriate buffers in order to be sent when the connection is re-established.

The mobile terminal application has been tested with the most popular mobile network providers in Austria: A1, Drei, T-Mobile, Telering, Orange, Yesss and Bob. It works correctly with all of them. In different areas, where rescue operations can take place, different providers can be used, depending on their signal quality. Furthermore, it depends on the user which provider will be used.

GPS is used to determine the actual position of the teams, the track they followed, and the position of important objects in the terrain. The GPS data are based on the standard NMEA-0183.

The mobile terminal can also send photos taken of the terrain. Supported formats are: JPG, JPEG, JFIF, PNG. Just one photo can be sent at a time which is transmitted only when the connection is established via the mobile network and not via satellite. Some text of description can be added which is hidden inside the photo by using Steganography. The required time to send a photo depends on the size of the photo and the connection quality. A notification is displayed in the Mission Control Center immediately upon reception of the photo.

As perspective for the future, this application should be available for smartphones running in other OS such as Android and iOS, as well as using other satellite networks (Iridium) and other global navigation systems (Galileo, GLONASS, COMPASS).

2.2 Mission Control Center

The search and rescue operation can be coordinated in the mission control center by using the viewer shown in Fig. 3. The coordinator is informed about the positions of the search and rescue teams during the operation and is able to communicate with them using this WebGIS application. The implemented viewer can be run by a common internet browser (e.g., Microsoft Internet Explorer or Mozilla Firefox) without being connected to the World Wide Web. In the center of the viewer, a map which can be adapted by the user is shown. An overview map of the whole rescue area in the upper left corner shows the current map section. As background, a high resolution orthophoto or the official Austrian Map can be chosen. The primary information is mission-related and displayed in the foreground:

- Position of mission control center, current position and track of each search and rescue team,
- POIs created by the mission control center and by the mobile teams,
- search sectors created by the mission control center.

These elements can be combined and shown in the map. The search sectors and POIs are created by a digitizing tool on the left side of the viewer. Search sectors define dedicated search areas for each mobile team. This information is stored in the central database and can be transmitted to the teams on demand. Further tools for adjusting the map are in the toolbar below the map. They allow zooming and panning, returning to earlier map views and other operations. Moreover, the symbols shown on the map are explained in a legend.

The main technology for generating the maps is the open source mapserver of the University of Minnesota (UMN MapServer), see [4]. Geodata such as orthophotos and the Austrian Map as well as mission-related information from the central database are merged by the UMN MapServer to a raster image which can be implemented in a web application. For every new map view, the client sends a request via the webserver to the mapserver. The mapserver accepts this request, calculates a new map view according to the requested parameters and responds on demand with a map, an overview, a legend and a scalebar. The skeletal structure of the viewer is based on the open source software Mapbender running under General Public License (GPL). It offers graphical user interfaces for orchestrating, viewing, navigating and querying geographic information.

Fig. 3: Web-based viewer of the Mission Control Center

Communication with the search and rescue teams in the field can be handled with tools on the right side of the viewer. The operation manager is able to send messages, POIs and search sectors stored in the central database. The process of sending a message to a team in the field, starts for example with writing the message and storing it in the database. Then, the communication tool is able to use this information to transmit it via the communication link. The process of sending POIs or search sectors works in a similar way. The operation manager digitizes POIs or search sectors within the viewer, adds an optional description and stores the objects in the database. Within the communication tool, these digitized elements can be used for sending information to the mobile search and rescue teams. In the other direction – when a mobile team sends information to the mission control center – the reaction depends on the type of message. In principle, the operation manager is informed when a new message arrives. After confirmation, the message is added to the list of received messages shown in the mid-right part of the viewer. Below this list, an integrity message is displayed. It shows the availability of the communication and GPS connection of the search and rescue teams in order to assess the actuality of the displayed positions. In general, all information exchanged between the mission control center and the mobile teams is stored in the central database realized by the freely available object-relational database management system PostgreSQL with the spatial extension PostGIS. This central database is the basis for the documentation and reconstruction of the entire search and rescue mission. Thus, debriefing is supported and a mission report can be created automatically after the search and rescue operation.

2.3 Communication Link

As briefly described in the previous section, the data transfer between the mobile terminals and the mission control center is performed by a hybrid communication link. Depending on availability, terrestrial mobile networks – data services like GPRS (General Packet Radio Service) and UMTS (Universal Mobile Telecommunications System) – and satellite communication systems are used (Fig. 4). In future, TETRA (Terrestrial Trunked Radio) might also be taken into account if available.

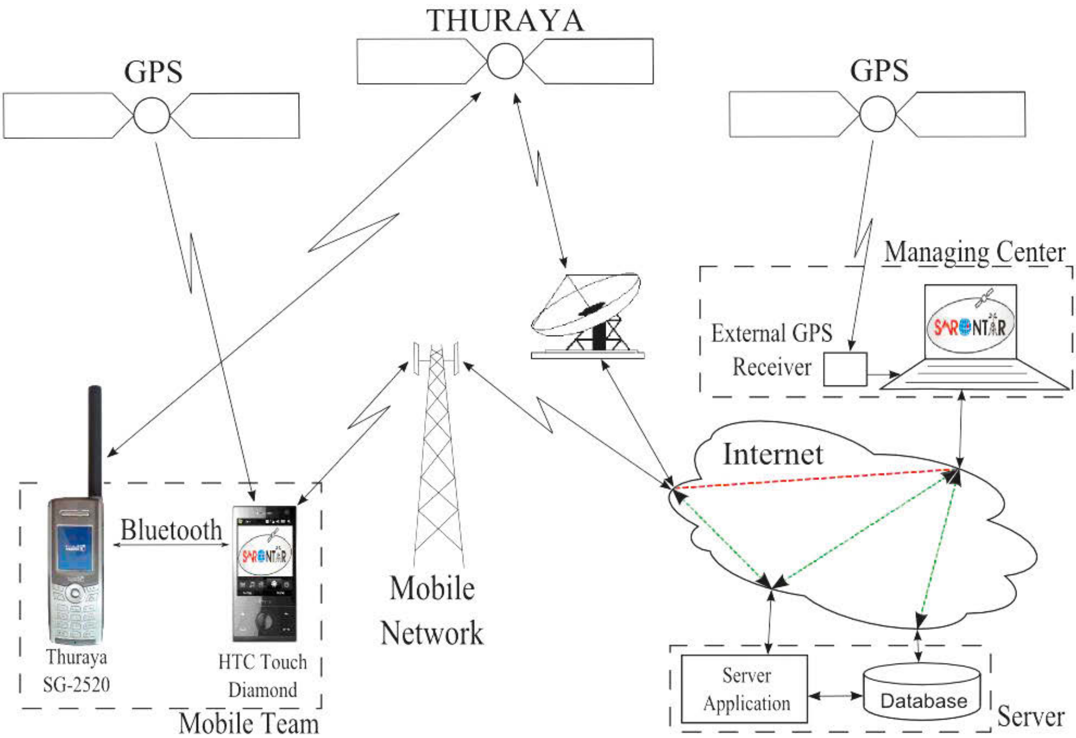


Fig. 4: Communication components in the context of the SARONTAR system

Within the development of the functional demonstrator, two mobile Thuraya satellite phones were used. The Arabian satellite communication system Thuraya comprises three components: ground segment, space segment, and user segment. The ground segment includes terrestrial gateway stations, which connect the Thuraya network to other telephone and data networks. The space segment consists of geostationary satellites with extra large antennas including hundreds of spot beams for a supply that is similar to mobile communication systems. The user segment comprises hybrid mobile satellite phones which can be used for satellite and mobile communication as well. The supply area of Thuraya ranges from Europe and North Africa to Central Asia. In the Alpine states, e.g., Austria, a minimal southern elevation angle of 30 – 35 degrees is necessary for using Thuraya services. The reasons to select the Thuraya system are the rather low operating costs – in comparison to other satellite communication systems – and the interoperability with mobile communication standards.

3. Practical Tests in Alpine Regions

The usability of the system was tested under real conditions several times. As an examples, consider the training exercise of the Austrian mountain rescue service on 13th March 2010 (Figures 5 and 6). The assumption for this training was that a group of ski mountaineers lost its way in the “Dachstein” mountains – a massif in Styria, Austria – due to a sudden change in weather and a following snowstorm. Six search and rescue teams of the Austrian mountain rescue service took part in this training. Through accompanying the training exercise with modern navigation and communication technologies, the innovative aspects of a satellite based rescue operation system became apparent compared to the current rescue organization (Table 1).

Current situation	Improvement through SARONTAR
Search paths for the respective teams are created via desktop GIS and afterwards transmitted via cable to mobile GPS devices.	Search paths can be created via the SARONTAR mission control centre and transmitted wireless to the mobile terminals.
Current positions of the rescue teams are recorded by the mobile GPS devices but not transmitted to the mission control centre. After finishing the rescue operation, the tracks of the teams are collected via cable connection and visualized on the desktop GIS for debriefing.	The positions recorded by the mobile terminals are sent to the mission control centre periodically in real-time and automatically visualized on the web-based map.
Current coordinates of the rescue teams are requested in different intervals via mobile phone or radio and thereafter recorded via the desktop GIS as point. Additionally, the current position of each team is marked in an analogue map.	The positions of the mobile teams are visualized as track on the web-based map of the mission control centre. On receiving a current position, the track is updated automatically.
Mobile and radio services are not permanently available in the alpine regions throughout the rescue operation. In case of missing voice communication, there is absolutely no information about the rescue progress.	The availability of communication is significantly improved through the SARONTAR satellite communication backup.
Operation-relevant spatial information is exchanged via voice communication between mission control centre and mobile teams.	Operation-relevant spatial data is recorded via map and sent to the communication partner automatically. Received spatial information is visualised on the map in turn. Therefore, the complex exchange of coordinates via voice is eliminated.

Tab. 1: Demonstrating the innovations and improvements achieved by SARONTAR

Fig. 5: The system under real conditions [www.bergrettung-groebming.at]

In summary, the developed system may significantly speed up the search and rescue operation. Through up-to-date information, the current status of the rescue operation can be distributed to all members of the rescue mission. Thus, an appropriate management of the rescue operation is assured from the very beginning.

The participants of the training exercise identified the following innovative aspects of the described system:

- The mission control centre improves the coordination of the rescue operation considerably.
- The whole rescue operation can be coordinated via a single control centre.
- Coordination and documentation of the rescue operation can be handled through the same system.
- The protocol of the rescue operation is prepared automatically and is instantly available after the operation.
- The rescue operation can be continuously supervised through up-to-date information. Therefore, the mission control centre is able to react quickly to unpredicted events.
- The user interfaces is simple and intuitive.
- Many advantages come along with the replacement of voice communication through text communication: higher availability; text communication is more unambiguous due to no interruptions (further inquiries or discus-

Fig. 6: Mission control centre during training exercise [www.bergrettung-groebming.at]

sions unnecessary); information transfer via text is kept short and concise; the mission control centre is able to prioritize incoming information (voice communication requires immediate reaction); no more overlaps like simultaneously incoming radio messages and/or phone calls; text communication is more neutral than voice communication (less emotions)

4. Outlook

One possible improvement is the additional use of autonomous sensors, e.g., accelerometers, magnetometers, gyroscopes and barometers [5]. Generally, the combination of GNSS and augmentation sensors will improve the navigation parameters accuracy, availability, reliability and integrity [6]. However, the main drawback of sensor augmentation is the need for extra hardware components.

As an alternative method without needing additional hardware, a step-by-step improvement of single frequency GPS positioning is discussed [7]:

- Step 1ab: Broadcast ephemerides and broadcast ionosphere model
- Step 1c: Troposphere model
- Step 2: Precise ephemerides
- Step 3: Differential code biases
- Step 4: Global ionosphere maps
- Step 5: Code pseudorange smoothing

The positioning accuracies in steps 1ab and 1c are consistent with the declaration of GPS Standard Positioning Service (SPS) for C/A-code (Coarse/Acquisition) receivers [8]. In step 2, precise ephemerides processed and provided by the International GNSS Service (IGS) are used instead of the predicted broadcast ephemerides [9]. For consistency reasons, the precise ephemerides refer to the ionosphere-free linear combination of the carriers L1 and L2. In case of received C/A-code pseudoranges, in step 3 differential code bias values are taken into account for achieving data consistency and thereby, improved positioning accuracy [10]. In step 4, broadcast ionosphere models are displaced by more accurate global ionosphere maps [11]. Finally in step 5, the noise level can be reduced by combining C/A-code data with carrier phase measurements.

The results of a static 24 hour data set with 30 seconds interval in Fig. 7, show the significant improvement of horizontal positioning accuracy

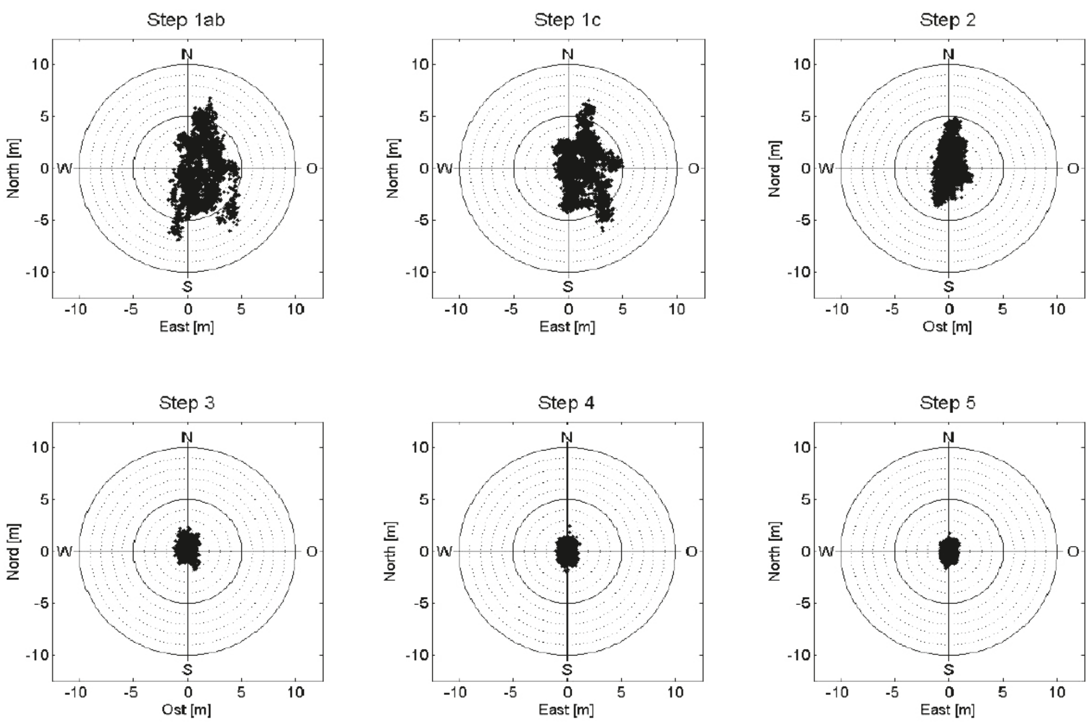


Fig. 7: Static 24 hour data set with 30 seconds interval

from 5-10 m (steps 1ab and 1c) to meter and even sub-meter level (steps 4 and 5). Also the vertical position component can be improved through this step-by-step approach of single frequency GPS positioning. The method described belongs to Precise Point Positioning (PPP) which currently is a topic of international research.

Another general goal for the future is to adapt the developed system for other emergency services like police, fire department or the Red Cross. Thereby, the cooperation between different emergency services would be enormously facilitated in the case of disasters.

Acknowledgements

(1) The development of the system has been funded by the Zukunftsfonds of the Federal State of Styria. Furthermore, the research activities have been supported by Senator h.c. Günter Bauknecht, a generous sponsor of the Universitätszentrum Rottenmann.

(2) Parts of this paper have been extracted and adapted from "Search and rescue optimization in alpine regions by satellite-based technologies". In: CD-Proceedings of the 1st GNSS Vulnerabilities and Solutions Conference, Baska, Croatia, September 7-9, 2008. Authors: H.P. Ranner, R. Prüller, K. Aichhorn, B. Hofmann-Wellenhof.

References

[1] *Aichhorn K., Hofmann-Wellenhof B., Ranner H.-P., Ofenheimer A., Schardt M., Prüller R., Bartelme N., Koudelka O., Schrotter P. (2007)*: SARONTAR I Final Report. Graz University of Technology, Institute of Navigation and Satellite Geodesy, October 2007.

[2] *Hofmann-Wellenhof B., Lichtenegger H., Wasle E. (2008)*: GNSS Global Navigation Satellite Systems – GPS, GLONASS, Galileo & more. Springer, Wien New York.

[3] *Berglez P., Hofmann-Wellenhof B., Plank G., Schiffer S., Matl H., Ranner H.-P., Vallant J., Schardt M., Prüller R., Bartelme N., Rautz K., Schrotter P., Vössner S., Brandstätter H. (2006)*: SARONTAR I Midterm Report. Graz University of Technology, Institute of Navigation and Satellite Geodesy, September 2006.

[4] *Prüller R. (2006)*: Visualisierung von Geodaten mit dem UMN Mapserver. Master thesis, Graz University of Technology, Institute of Geoinformation.

[5] *Weimann F., Abwerzger G., Hofmann-Wellenhof B. (2007)*: Let's Go Downtown! Let's Go Indoors! Pedestrian Navigation in Obstructed Environments. GPS World, 18(11): 26-34.

[6] *Hofmann-Wellenhof B., Legat K., Wieser M. (2003)*: Navigation – principles of positioning and guidance. Springer, Wien New York.

[7] *Le A.Q. (2004)*: Achieving Decimetre Accuracy with Single Frequency Standalone GPS Positioning. In: Proceedings of ION GNSS 17th International Technical Meeting of the Satellite Division, Long Beach, California, 21-24 Sept. 2004, 1881-1892.

[8] *Department Of Defense (2001)*: Global Positioning System standard positioning service performance standard. Available from the US Assistant for GPS, Positioning and Navigation, Defense Pentagon, Washington DC.

[9] *Kouba J. & Heroux P. (2001)*: Precise point positioning using IGS orbit products. GPS Solutions, 5(2): 12-28.

[10] *Schaer S. & Steigenberger P. (2006)*: Determination and Use of GPS Differential Code Bias Values. IGS Workshop Darmstadt, Germany, 08-11 May 2006. Available at http://nng.esoc.esa.de/ws2006 (29.01.2008).

[11] *Schaer S. (1997)*: How to use CODE's global ionosphere maps. Astronomical Institute, University of Berne. Available at http://www.aiub-download.unibe.ch/ionosphere/doc (29.01.2008).

Contacts

Mag. Claudia Fösleitner, TeleConsult Austria GmbH, Rettenbacherstraße 22, 8043 Graz, Austria.
E-Mail: cfoesleitner@teleconsult-austria.at

Driton Kuçi, TeleConsult Austria GmbH, Rettenbacherstraße 22, 8043 Graz, Austria.
E-Mail: dkuci@teleconsult-austria.at

Univ.-Prof. Dr. Dr.h.c.mult. Bernhard Hofmann-Wellenhof, Technische Universität, Institut für Navigation, Steyrergasse 30, 8010 Graz, Austria.
E-Mail: hofmann-wellenhof@tugraz.at

Dipl.-Ing. Hans-Peter Ranner, Goldbichl 12a, 8786 Rottenmann, Austria.
E-Mail: hp.ranner@gmx.at

Dipl.-Ing. Mag. Rainer Prüller, Technische Universität, Institut für Fernerkundung und Photogrammetrie, Steyrergasse 30, 8010 Graz, Austria.
E-Mail: rainer.prueller@tugraz.at

Dipl.-Ing. Klaus Aichhorn, Universitätszentrum Rottenmann, Technologiepark 2, 8786 Rottenmann, Austria.
E-Mail: aichhorn.klaus@uzr.at

vgi