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Performance of the joint Slovenian - Austrian lightning location network

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Abstract:
In 1988 the joint Slovenian - Austrian lightning location network was installed. This lighting location system is a cooperation between EIMV (Elektroinstitut Milan Vidmar) and ALDIS (Austrian Lightning Location and Information System).
The most important performance parameters of lightning location systems are the so called detection efficiency (DE) and the location accuracy. In this paper we present estimates for both performance parameters.

1. Introduction:

The joint Slovenian - Austrian lightning location network consists of 2 Slovenian sensors and 8 Austrian sensors. The Slovenian sensors are from the type LPATS III and the Austrian sensors are IMPACT. The main difference in technology between these two types of sensors is that the IMPACT sensor measures the angle to the lightning impact and the arrival time of the lightning field whereas the LPATS III sensor only measures the arrival time of the lightning field. Fig. 1 shows the basic network configuration.

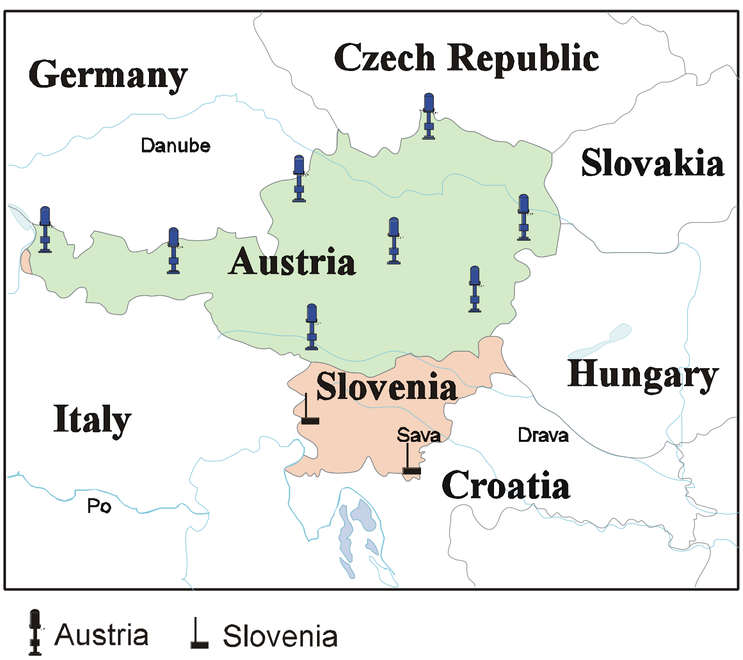

Fig. 1: Network configuration of the joint Slovenian - Austrian network

The raw sensor data from the Austrian sensors are sent over X.25 links to the network center in Vienna. Raw sensor data from the two Slovenian sensors are sent over the Internet to the Austrian network center. All the sensor data are used in a location algorithm running on a SUN workstation. This location algorithm groups all the sensor data according to time information and calculates afterwards an optimum location for each individual stroke. A separate process combines strokes located inside a geographical and temporal window to a flash.

2. Detection efficiency:

Talking about detection efficiency (DE) of a location system it is necessary to distinguish between two different types of DE, the stroke and the flash detection efficiency [Rubinstein, 1995]. The flash detection efficiency is defined as the fraction of flashes detected from the total number of really occurring flashes. The stroke detection efficiency is defined the same way regarding the individual strokes. Rubinstein [1995] has shown that the relation between stroke and flash DE strongly depends on the distribution of the number of strokes per flash and that the flash DE can be appreciably higher than the stroke DE.

Determination of ground truth data (the real number of flashes or strokes occurring at a certain location) for proving the DE of a network requires a high experimental effort (video cameras) [Mach et al., 1986; Idone et al., 1998]. Therefore theoretical models are normally used to estimate the detection efficiency of a location system.

To check the relative sensor performance the relative sensor DE over a certain period is used. Relative sensor DE is the number of flashes (strokes), where a certain sensor contributed to the location versus the number of flashes (strokes) detected by the entire network.

2.1 Estimation of the flash DE with a DE model [Schulz, 1997]

The DE of an individual sensor is basically determined and limited by the following parameters [Diendorfer et al., 1994]:

- Trigger level of the DF
- Saturation limit of the DF
- Waveform discrimination

To locate a lightning flash with a combined network of IMPACT and LPATS sensors, a minimum of two IMPACT sensors or one IMPACT sensor and two LPATS sensors reporting the flash is required. Based on these assumptions Fig. 2 shows a DE estimation for the joint network under consideration of the different information provided by the sensors of different technology.

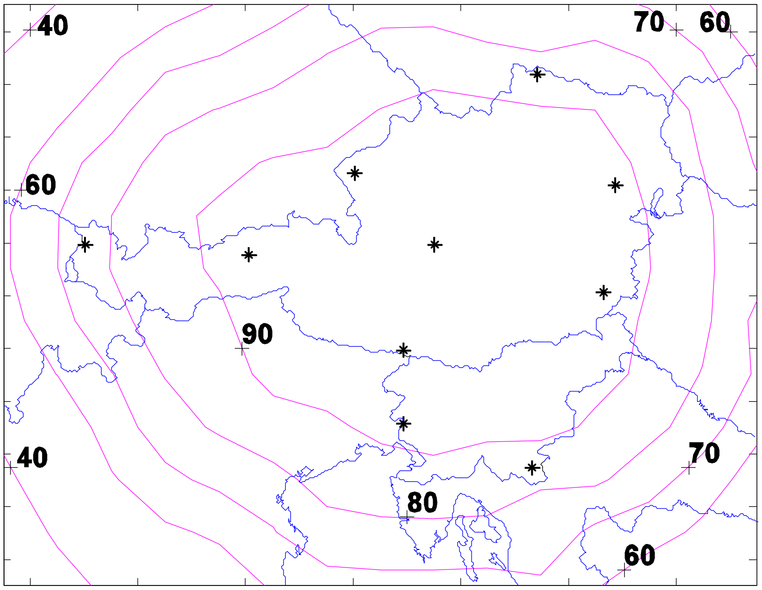

Fig. 2: DE estimation of the joint Slovenian-Austrian network
Threshold th=70 mV (IMPACT), th=100mV (LPATS)
Damping constant X=1.23
Current distribution with I_{median}=16 kA and s=0.6

From Fig. 2 it is obvious that in main parts of Slovenia and Austria the DE is higher than 90 %. The reason for this very high DE is the small baseline between the individual sensors.

2.2 Relative sensor DE

Relative sensor DE is a good parameter for comparing the sensor DE performance of the individual sensors and gives also some indications of the overall performance of the network in some regions. Fig. 3 shows the relative sensor DE's for July 1999. A relative sensor DE of 70 % at a certain distance D means, that this sensor participated to 70 % of flashes located at a distance D around the sensor location. It can be seen that the sensor in Cromelj has a better DE performance than the sensor in Nova Gorica. One reason for this difference is that the sensor in Nova Gorica was out of service for about 27 hours where the sensor in Cromelj was out of service only for about 18 hours over the month of July 1999. Most of the time this outages related were to communication problems on the serial links between the sensors and the EIMV Internet router.

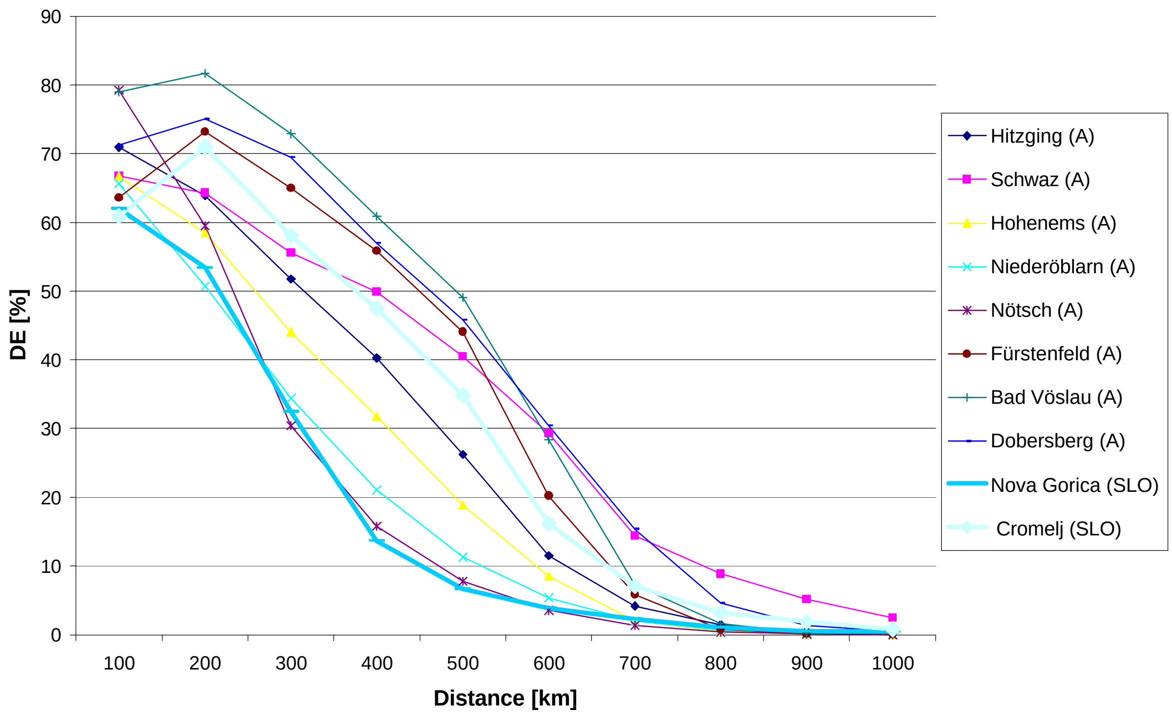

Fig. 3: Relative sensor DE for July 1999 versus distance

Another reason for a better performance of a sensor is the electromagnetic environment of the sensor. A lower noise level provides a better sensor performance. Further it makes a difference in the DE characteristic whether the sensor location is inside a mountain valley or not. The Austrian sensors in Schwaz, Hohenems and Niederöblarn are examples for sensors located in valleys and therefore there DE characteristic falls off more rapidly with distance compared to a sensor in a flat area (e.g. Bad Vöslau).

3. Accuracy:

As already mentioned before accuracy is another important performance parameter of a lightning location system. The accuracy of an individual stroke location is affected by several parameters:

! Standard deviations of the angle and time measurement:

Of course the accuracy of the angle and time measurements influences the accuracy of the calculated location. These standard deviations are “mean” standard deviations for a large number of measurements and not the standard deviations of the individual measurements from a single stroke.

- ! Number of sensors reporting:

  This value is mainly dependent on the DE of the network and therefore also dependent on the peak current of the stroke. A stroke location calculated from three or more IMPACT sensor messages is normally more reliable than a stroke location calculated from two IMPACT sensor messages only.

- ! Sensor location relative to the stroke location:

  The accuracy also depends on the position of the stroke location relative to the sensors. Obviously a stroke only reported by sensors far away from the stroke location will not be as accurate as a stroke reported by sensors very close to the stroke location.

Basically there exist two different approaches to estimate the accuracy of a lightning location network.

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(1) Analysis based on theoretical investigations:

- ! DE model plus axis of error ellipses:

  By applying a DE model and calculating the semi major axis for locations distributed over the entire network it is possible to estimate the average regional accuracy of a lightning location network.

(2) Analysis based on real (ground truth) lightning data:

- ! Comparison with known lightning locations using one of the following approaches:
  - a) Triggered lightning: This method requires of course a high effort and is therefore not used very often. It also gives accuracy information only for the trigger site and not for the entire network.
  - b) natural lightning: Known locations of natural lightning including exact timing are very rare. Therefore this method can also provide only a rough estimate of the accuracy of the entire network.
- ! Comparison with power line outages
- ! Comparison with impacts to telecommunication towers

3.1 Accuracy model

Fig. 4 shows a contour plot of regions with the same semi-major axis of the 50% error ellipse [Schulz, 1997]. For this plot first the reporting sensors were determined with the DE model for a single lightning peak current of I=15 kA and a threshold value of 70 mV. Fig. 4 estimates the accuracy for a single lightning peak current (15 kA) by using all the information provided by the sensors (angle and time for IMPACT sensors; time only for LPATS sensors) . The accuracy in Fig. 4 is given in unit km.

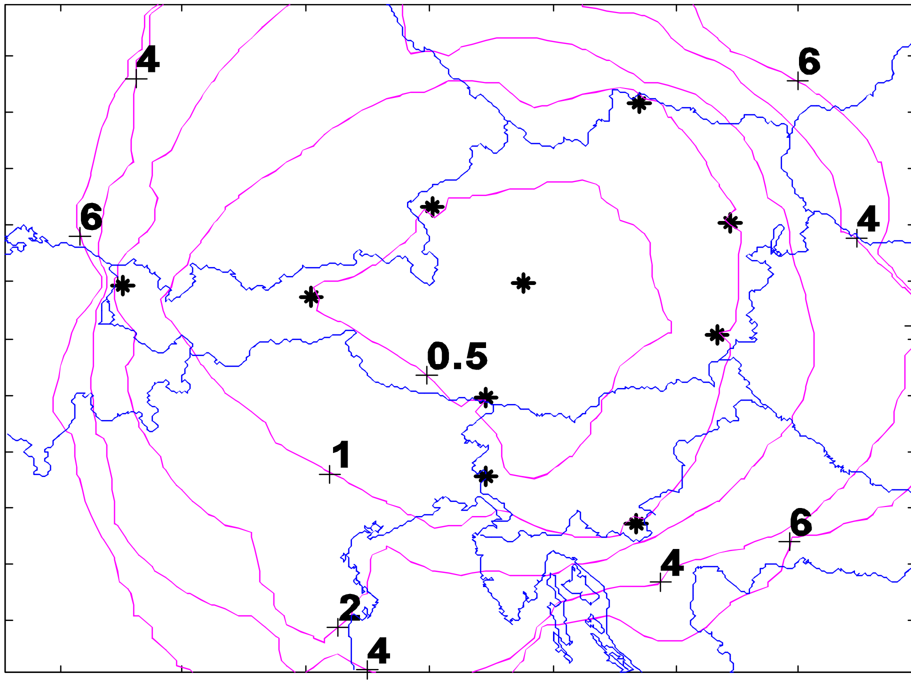

Fig. 4: Accuracy plot for the joint Slovenian -Austrian network

All the accuracy estimates using a DE model show the same tendency for the joint network. The accuracy is quite good (better than 1 km) in the eastern part of the network and decreases in the western part of Austria.

3.2 Comparison with power line outages

271 power line disturbances in the high voltage network of the Austrian Electricity Supply Board were reported in 1995. This number includes all automatic reclosures and all line outages in 1995. 184 of the 271 power line disturbances were of unknown failure reason. From these disturbances of unknown failure reason 53 were correlated by time with lightning flashes. The comparison was made with flashes because the timing of the power line disturbances is only accurate in the range of seconds and therefore it is not possible to correlate outages to the individual strokes responsible for the disturbance. Further 19 line disturbances were not correlated with a particular flash but there was thunderstorm activity in the surrounding of the power line.

A flash is considered to be time correlated to the power line disturbance if the time difference between the power line disturbance and the flash is less than 1 second and the perpendicular distance (minimum distance) to the power line is less than 5 km. Fig. 5 shows the minimum distances between the locations of the correlated flashes and the power lines in 1995. The investigation reveals a mean distance of 840 m and a median of 550 m for 1995.

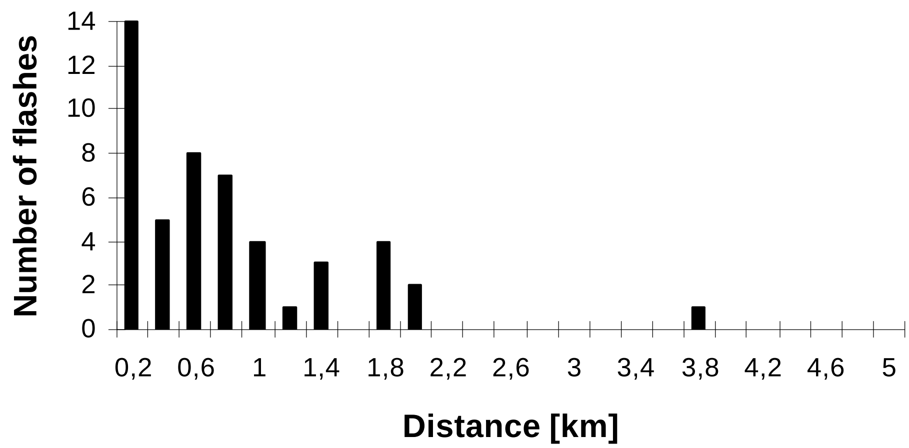

Fig. 5: Perpendicular distances of location of flashes time correlated with power line outages to the power lines (1995)

4. Summary:

The most important performance parameters of lightning location systems are the DE and the accuracy. We have shown the result of a DE analysis of the joint Slovenian-Austrian lightning location system which indicates a DE of more than 90 % in the main parts of both countries. This theoretical result is also supported by our experiences with damages reported to insurance companies.

We have further shown that theoretical accuracy estimations are in good agreement to practical accuracy estimations with power line disturbances. The accuracies are in the same range although the time of the disturbance was not known to the millisecond and thus it was compared to the flash location only. A problem with this type of investigation is that the actual striking point on the line is not known and thus the accuracy is probably overestimated.

We want to emphasis that this lightning location system with this small distances between the individual sensors is one of the best performing lightning location systems all over the world

5. References:

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