IMPLEMENTING GIS TECHNOLOGY FOR QOS IMPROVEMENT IN TELECOMMUNICATION NETWORK (HIGH ACCURACY FAULT LOCATING)

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Abstract: *Faults in telecommunication network have direct impact on network and service availability and maintenance costs. Those are the main reasons why efficient fault elimination, fault prevention and removal of their causes are of special interest. Possibilities that arise from the implementation of new technologies, such as GIS systems and tracking systems for fault locations, can significantly help telecom operators to reduce network down-time, improve its quality, and therefore quality of services that are provisioned by that network. This paper describes problems and their efficient solutions as a result of GIS system implementation in Croatian Telecom - TK center Rijeka. The implemented GIS system covers many more phases in the lifecycle of telecommunication network [1][2], and the aim of this paper is to present a GIS approach to high accuracy fault locating.*

KEYWORDS: Telecommunication network, QoS, Fault location, GIS, GPS

INTRODUCTION

In the near past, primary goal for most telecom operators in developing countries like Croatia was to reach all potential customers with telecom infrastructure for POTS, and to do it fast. Croatian Telecom, as an operator in such a country followed the same premise of fast construction of the national telecommunication network. Despite the war situation, the results achieved in last 10 years, considering penetration of telecommunication services as well as implemented technology in the Croatian national network [3] brought Croatian telecom to the point where it could service customers with strickter quality of service demands.
Modern telecoms are faced with two key issues today:

- to satisfy customers' demands and in the same time maximize profits and
- differentiate services based on QoS (Quality of Service) requirements.

Among other quality parameters, availability (in other words - expected downtime) is proven to be the most significant factor in choosing QoS grade that the customer is ready to pay for. User acceptable downtime for critical, high priority

connections, can be only few minutes per year (e.g. 99.999% availability). But, more likely, few hours downtime is acceptable for most customers and most of the services.
Considering the fact that it is not economically justified to build fully redundant network (equipment, lines etc.) for all telecommunication services, different faults occur in network. Competition between telecom operators to improve availability factor, and to reduce network downtime, brought to the surface the fault handling problem importance with all its dependencies. To achieve the availability goal, there are two crucial issues: how quickly telecom operator could detect exact fault location, and how efficiently a repair team can be dispatched to the precise location.
In this paper we will not handle problem of active network equipment faults, because it is a common practice to have redundant active equipment for critical services and customers. Also, it is not the main purpose of this paper to discuss the detailed modelling issues of measurements in local access network. Rather our emphasis is to show design and implementation procedures and GIS technology implementation in the fault tracking and locating system that should become a standard building block for the company decision support system.

1. PROBLEM DESCRIPTION

When problem was initially defined, the main topics that needed to be addressed immediately were

- is it possible to use data from current GIS-based documentation system,
- what is the quality of this data and
- how fast could it be implemented in current fault locating process?

The next important question was whether a new GIS/GPS combination of technologies could be used along with measurement results to calculate exact fault location and to provide detailed maps of surrounding areas. This has to be done in order to enable repair teams to find exact fault location even in the worst weather conditions or at night when it is difficult to find precise orientation marks.
Generally (as Croatia is not so density populated), backbone network which connects major Croatian cities is passing mostly through uninhabited areas (forests, or bura blasted - desert like areas on some islands) with low number of significant reference points. This fact creates serious problem when necessities to find exact fault location emerge..
At the same time, one should have in mind that every Telecommunication center in Croatia has got well-defined measurement methods and is generally equipped with high quality geodesy instruments.
Traditionally, the repair team (after a fault was registered) had to go to documentation department, seeks for documentation of implied cable, make measurements (with OTDR or similar instrument) and then makes some calculations to find where the fault point is. Upon arrival on fault area, if there are

some good reference objects, fault location can be tracked relatively easy. But, as previously mentioned, in majority of the cases (forests or areas with no clear marks) the repair team looses precious time.
We propose the solution in which all repair teams are equipped with GPS system, which can navigate them on exact location with positioning error of few meters. This solution also provides them with high accuracy spatial data from GIS system (maps and aerial photo), which could extend their information about fault location. As the manufacturer defines the instrument precision and quality of measurements, the area where telecommunication operator can make significant improvements is quality of its telecommunication GIS system. In following text we will be discussing some of the fundamental issues of this approach.

2. THE SYSTEM

The main source of data for this system is telecommunication GIS system. GIS system of TK center Rijeka contains 2700 geo-referenced maps of various precisions (from 1:500 to 1:100000). Standard national map is 1:5000 and entire county is covered by this precision. Maps in scale 1:1000 (and some 1:500) are standard for urban areas. Also some satellite and aerial photography (Fig. 1) is used in this system. The main problem with cartographic maps is that majorities of them are quite old (10 – 25 years) and therefore many of new artifacts and reference points are missing. This problem could be, and is, solved by usage of aerial photography techniques, which can quickly generate additional information (maps) for selected areas.

Figure 1 - Aerial photography (2000 ft flight height)

GIS database currently holds site and schematic cable diagrams, duct and manhole drawings as well as switching equipment location and capacity. Geo-referenced building and equipment locations with fault data attached are available for analysis. Up to now primary purpose of the GIS in TK center Rijeka was to support network operations and maintenance. Practically all our departments use

this database, primarily for real world visualization of telecom infrastructure, localization of demand for new lines, equipment and cable failure troubleshooting.
When the GIS database was created, the primary goal was to establish connection between alphanumerical data in SQL DBMS and geo-referenced information contained in numerous AutoCAD schematic and site drawings.
Along with telecom data, GIS database contains data from the local Power Company (high voltage installations, transformers), water installations, flood data etc. External meteorological database contains detailed data (daily acquisition) from many locations with temperature and precipitation. In the future, special attention will be paid to adopt data acquisition and preparation procedures that will emphasize the importance of collecting new details in addition to O&M related data, and this is the direct consequence of the development and implementation of described system.

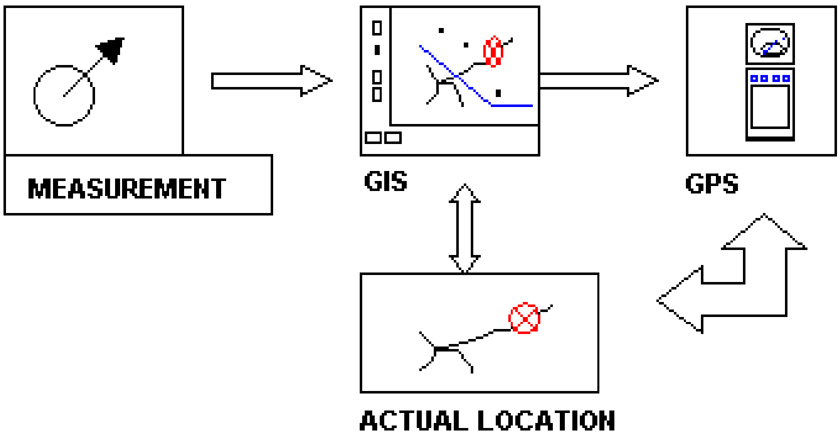

Figure 2 - General model of fault locating in telecommunication network

Generally, the process of locating a fault can be dissolved in several steps (Fig. 2):
1. Perform measurement for affected cable from reference point for that cable (usually switch location)
2. Enter measured distances in GIS system which will trace affected cable and find location (geographical coordinates) of fault, print detailed maps of surrounding areas and provide additional data (about gas installations or electric cables or other infrastructure in proximity)
3. Enter coordinates from GIS system in GPS navigator
4. GPS navigator leads repair team to fault location
5. After successful fault point location, fault repair team has to return all information to documentation system so that a documentation check is done, and eventual corrections (wrong location data or similar) are applied to GIS system

As seen in fig. 1 aerial photography is very good choice for exact locating of faults, but first some problems must be resolved.

3. AEROPHOTOGRAPY, MAPS AND GIS

A wide range of new developments in both hardware and software technologies is leading to very rapid changes in the arts of map making and map correction or updating. Remote sensing, air or satellite based optical or radar imaging can collect data covering wide areas. Points can now be fixed very quickly by GPS to far higher accuracy than by the traditional theodolite triangulation. Data stored in digital format can be manipulated at high speed to transform and correct geometry, datum and projections or to select and classify or match data automatically.

3.1 A definition of map ...

In the past most of the available maps were ‘analogue’ pictures of a geographical area. Now we consider maps as a geographically referenced database - the drawing, or image on a screen, is just a convenient visualization way, an index, to make it easy to find the right figures quickly and with minimum effort and minimum of mistakes or misinterpretations.

3.2 The key parameters of any map

Relevance - the map has all the data required for the user's task/s. It is up-to-date, 'fit for purpose' - quality, specified provenance and accuracy, projections and datum clearly specified.

Completeness - all the data in any specified class is presented in the map – all objects in a given class included - or any gaps, omissions or changes in standards or definitions clearly indicated.

Accuracy - Implied accuracy in x, y and z. Actual accuracy in x, y, z, or the differences between the mapped and actual - in ’ground truth’ positions.

Resolution - the scale intervals of measurement.

A sensor may have a basic discrimination of a few centimeters - this may allow the measurement of the distance between two nearby objects to a similar accuracy - very high precision, yet the x, y, z co-ordinates may be many meters from their true position - low accuracy.

3.3 The 'z' problem

Maps are flat two-dimensional surfaces - the terrain is not! The problem is how to map objects at varying heights - z's, to transform the three x, y, z co-ordinates on the image into the correct x, y co-ordinates in the flat reference-mapping plane.

This is a particular problem when mapping photographic data. Any point, on the nadir, directly below the sensor will be projected in its true position. Any features viewed 'on the slant' - towards the edge of the image will be displaced - the

parallax effects if there is any difference in the height - the 'z' position, from the rest of the imaged scene.
If the feature is on higher terrain than the nadir point it will appear to be further from the center in the x or y direction. If it lies below in a depression or valley, it will appear as being closer to the nadir, or center point, than it's true position.
This is the basic problem of ortho-correcting images. For a standard 1:10,000 air photograph the image subtends an angle of over 35^0 each side of the vertical -> 70^0 total. Then a difference of height of only 1.0 m between the center and an object at the edge of the image will create a false, lateral, displacement of 0.74m, of more than 1 m in the corner of the scene and around 0.35m at the edge of the overlap zone. For Small Format imaging the angle is less, +/- 26^0, typical x, y displacements are 0.47m edge and 0.25m overlap zones per meter of height difference.
This is an area where satellites, especially high-resolution systems such as Ikonos, have an advantage. Although the viewing angle may be up to 40^0 from the vertical, typically 200, the imaging distance is so large that the subtended angle across the image is less than 1^0. This means that the views are effectively parallel and the same angular correction can be applied across a whole scene.
In all cases any errors in the elevation, z, will lead to horizontal, x, y errors varying from zero to 100% across the image. The lack of accurate z data is generally the limiting factor to ortho-accuracy when deriving or correcting maps from remote image data.

3.4 Ortho-correction

Given the off-nadir angle and the height, z, difference it is a simple geometrical calculation to work out the changes to apply to correct the observed to the true x, y position. There are three basic techniques for ortho-correcting the positions of objects at varying heights onto a 'flat' (over typical local surveying areas) mapping x, y plane:

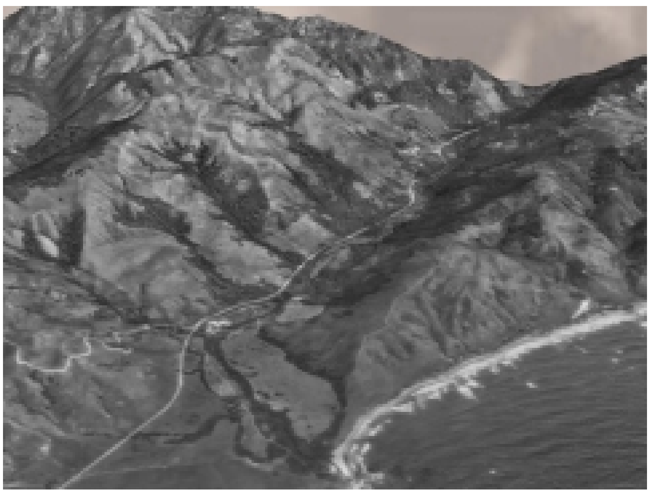

Figure 3 - Orthophotography with DEM of same area

.1 Match each point with a z measurement for the corresponding x, y point from a Digital Elevation Model - DEM. All modern mapping programs have efficient computational algorithms for combining image with DEM's to produce ortho-corrected data sets. The accuracy of the transformations depends on the density and the accuracy of the DEM data points (Fig. 3).

.2 Combine images of the objects from two directions to merge in a 'stereo' image - the relative displacements to merge the images give a measure of the z dimension. This can be used to generate full three-dimensional data sets from pairs of overlapping images. Using optical viewers, this photogrammetry was a very slow, tedious, labor intensive and therefore expensive task. With digitized data the same technique can be applied by automatic computer matching. This avoids the costs, and errors from human operators but can give rise to misleading results.

.3 Correct to an existing two dimensional map. By comparing the image co-ordinates of objects with their co-ordinates on an existing accurate x, y, map - ground control points, the distortions due to the sensor system - camera, and the elevation effects can be modeled and then applied as a polynomial or complex 'rubber sheet' correction to resample the image with all points displaced to correct to the two dimensional map. This is a computationally intensive process but newer algorithms used with modern high-speed computers make it rapid and reliable.

.4 If high accuracy needs to be achieved - mm or cm accuracy - measurements can be made directly with a GPS set! Modern GPS sets is now far more accurate than the traditional theodolite and triangulation methods. There are still problems as the GPS data is referred to a reference ellipsoid but traditional surveying is based on vertical gravity defining a geoid reference surface which may not be parallel to the mathematical model and may not be flat due to the gravity anomalies from the local geology.

.5 The new development of line-scan digital imaging systems will make traditional airborne photographic photogrammetry obsolete in the next two-three years. These systems analyze three concurrent line scans in near real-time and produce full high resolution ortho imagery directly with no further ground based processing.

3.5 What are we trying to do - the value of data?

There is a tendency when using modern high performance technologies to go out, make measurements on a regular grid pattern, process all the data, and make a complete and uniform cover of all areas under study. This avoids having to think and make decisions - 'and anyway it may be useful sometime'.
Map updating is essentially a reconnaissance function - to detect new information in a cost-effective way, rather than repeating an overall mapping function.
Uniform sampling or specification can lead to unnecessarily large databases. These require extensive storage and interfere with CAD and GIS analysis as access is

slowed down when retrieving information. It is easy to collect bulk data - the art is to pick out and to process and store only the useful part - the information.
Island of Krk, part of the Telecommunication center Rijeka area, was chosen for pilot project of high accuracy fault locating. There are about 83 maps of 1:5000 scale, which cover the island of Krk. Some of these, such as the maps covering the towns, are very rich in data and information. Others are data poor. The bura blasted, bare rocky areas in the southeast (Fig. 4) have no active telecommunication infrastructure and little or no prospect of any developments in the near future so there is no need for any detailed information about them. If the images are processed using the same DEM pattern and scanning density over the whole island, these areas occupy the same data space per km^2 as the active urban areas.

Figure 4 - Southeast part of Island of Krk

This 'Pareto Law' of data - 20% of the data contains 80% of the information, the remaining 80% of the data contains only the last 20% of information, applies well to Krk island and also to the whole of Croatia.
In particular the vertical information, the DEM's, tend to be both the limiting factors which determine the accuracy - and cost more than the horizontal coordinate information.
There are existing low cost - but low accuracy, data sets, which, used with existing contour maps, are adequate for 3D modeling of terrain for view-line analysis, but inadequate for accurate ortho-correcting. ‘Z’ data already exists in the maps of the densely urbanized areas. It can be easily measured to cm accuracy along the roads and for more isolated objects.

3.6 Final recommendations

The implication of previous discussion is that managers should use their effort and money selectively to get the best economic return from selectively processing only the information that supports their decision-making and management tasks within their organizations.

In our case, after detailed analysis (technical and financial) a combination of methods shown at 3.4.1 and 3.4.3 was chosen for pilot project. These methods, used with appropriate preparations and with aerial photographs of 20 cm resolution, allowed us to build high precision image database with minimum cost and storage need.

4. SOFTWARE

After completing image database with aerial photographs and other geo-referenced data, focus has moved towards the problem of modifying existing GIS software to implement new features, which will enhance and speed up repair works. As the majority of previously developed software (Fig. 5 and 6) is modular, new features were added in the same way, to preserve modular structure and all its benefits.
In our case, GIS database is build using AutoCAD Map 3.0 and ESRI ArcView 3.1 standard programming tools, and all needed data were prepared using those tools.

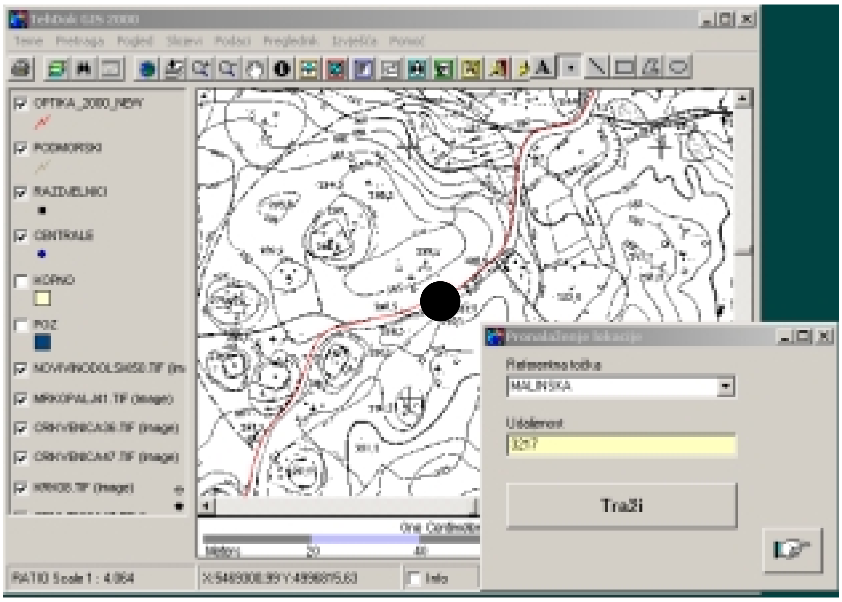

Figure 5 - Fault locating with 1:5000 map as background

The FALOC (Fault Locating) system is implemented in Microsoft Visual Basic 6.0 and ESRI MapObjects 2.0. It has user-friendly interface, and it is possible to choose various types of background resolutions (maps from 1:500 to 1:25000, satellite and air-photo images), find coordinates of fault locations based on distances from reference points and cable path, etc.

5. FURTHER WORK

At this moment a fault-handling operator has to manually input data from measurement instruments and transfer coordinates to GPS system. Therefore, next improvement will be to establish communication interface between GPS system and measurement equipment. With that approach it will be possible to make automated input of measurement data, which will give additional value in further automation of fault-handling process.

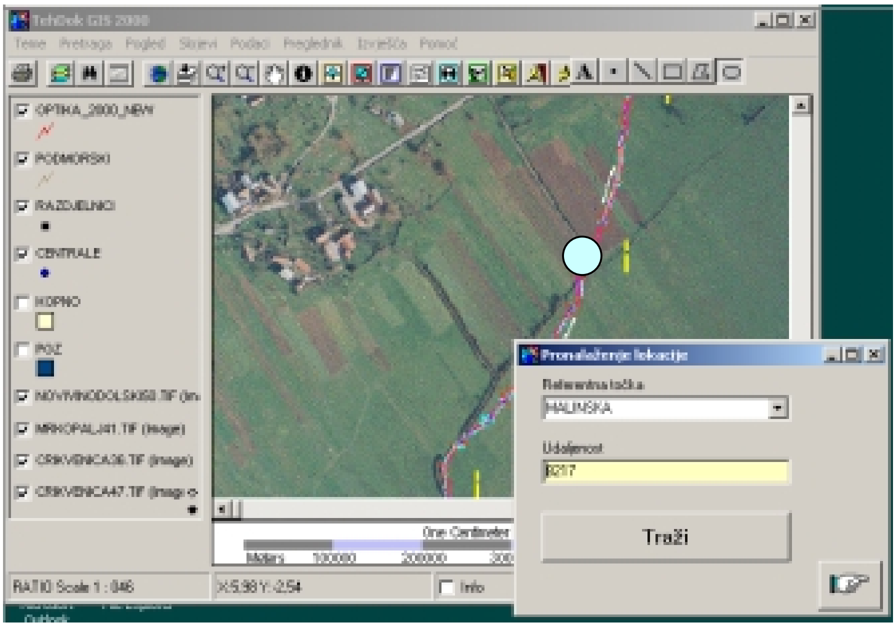

Figure 6 - Fault locating with 2000ft aerial photo

6. SUMMARY AND CONCLUSIONS

As telecom operators in central and eastern Europe countries are moving towards deregulation and soon will face strong competition, one of the most important factors of success on open market will be the quality of service, which operators will be able to deliver to their customers.

This project has demonstrated successful implementation of advanced technologies in order to improve fault location accuracy, which is one of important fault handling features. It is also proven that this task very quickly shows its value and is solved much easier if a company already has an operational and well-designed GIS system.

REFERENCES

[1] D.Medved, K.Brlas, D.Šarić "Fault Analysis and Prediction in Telecommunication Access Network", Proceedings of MeleCon 2000, pp. 136-139., Limassol, Cyprus

[2] M.Valković, B.Lukić, D.Medved, D.Čišić "Design and Implementation of Telecommunication Access Network Expansion Planning System", Proceedings of ConTEL 1999, pp. 257-264, Zagreb

[3] V.Brlić, V.Žurić-Hudek, J.Buzolić, N.Rožić, D.Begušić: "The Croatian Telecommunications Way Towards the Communications Era", IEEE Communications Magazine, Feb. 2000, pp. 98-106.