“REMOTE SENSING, COMMUNICATIONS AND INFORMATION TECHNOLOGIES FOR VEGETATION FIRE EMERGENCIES”

Ing. Alberto Laurenti
consultant of Teletron Electronics S.r.l.
Via Agostino Bassi, 33 00191 Rome, Italy
E-mail: riccardo.laurenti@ac.com
Tel.: 39-335-340409

Prof. Alessandro Neri
Electronic Engineering Dept., Università di Roma III
Via C. Segre, 2 00100 Roma
E-mail: neri@infocom.ing.uniroma l.it
Tel.: 39-6-44585466
Fax: 39-6-4873300

REMOTE SENSING, COMMUNICATIONS AND INFORMATION TECHNOLOGIES FOR VEGETATION FIRE EMERGENCIES

A. Laurenti*, A. Neri**

* Teletron s.r.l. Cagliari Italy **Elecronic Engineering Dept. Università di Roma III Rome - Italy

Abstract

The amount and the efficiency of the resources needed for the suppression of a vegetation fire event is highly dependent on the time of intervention. The paper describes how state of the art remote sensing, communications and information technologies have been integrated into a coherent design to obtain a surveillance and control system (the Teletron B.S.D.S.).

Keywords: Vegetation fires, surveillance and control systems.

1 Introduction

In many countries, the fight against vegetation fires has required the set up of complex hierarchical organisation of command and control centres. The Local Operations Centre (LOC) is at the lowest level of the command chain and it may be responsible for the prevention and the suppression of fires within a typical range of about 30 Km.

To accomplish this kind of mission, operational units are normally assigned to the LOC command which should be able to employ them in the most efficient way.

In order to reduce the reaction time of the fire suppression forces, a preventive action is represented by the assessment of the fire injection and propagation risk. In general, this figure is dependent on the distribution of the vegetation on land, on the fuel moisture content and on the seasonal and weather conditions; an estimate of the risk typically requires the local measurements of wind speed, temperature, air humidity, and other terrain related parameters.

After a fire ignition, the detection and alarm should be immediate in order to prevent a wide spreading of the fire and to limit the amount of resources and time needed for the attack and suppression. On the other hand, a short reaction time for the intervention can be assured only by a high degree of co-ordination of the available forces. In this respect, the role of the LOC is important and communications and co-ordination among forces can represent a key factor for the success of the intervention.

The application of Infrared TV cameras has been proved to be a valid solution to the problem of the automatic vegetation fire detection when suitable image processing and communication techniques are adopted. IR sensors for the detection of smokes [1] can be suitable especially in the case of flat countries. When the terrain presents hills or mountains a fire spot detection approach [2] such as the one proposed here has achieved significant operational results.

Teletron has installed in Sardinia 21 *Bright Spot Detection System (B.S.D.S.)* autonomous and remote sensor stations and 5 surveillance and control systems, one for each local operations centre. The total surface actually covered by the centres amounts to about 6.500 square kilometres and the first B.S.D.S. station became operational in 1986. The technical and operational experience acquired by Teletron during the last ten years is now used to develop the new generation of sensor stations in the frame of the European DEDICS project.

2 The B.S.D.S. surveillance and control system

A functional block diagram of one of the *BSDS Surveillance and Control systems* is shown in fig. 1. Since the system has a modular hardware architecture, based on different commercial components connected through a local area network, alternative configurations are possible, depending on the specific operational requirements.

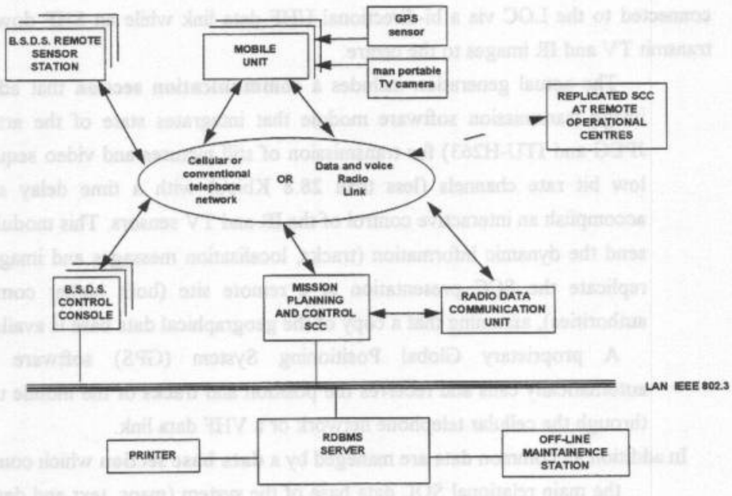

Fig. 1: the system architecture of the Local Operational Centre

A basic configuration includes at least a surveillance section and a mission planning and control section.

The surveillance section comprises:

one or more (typically three) B.S.D.S. remote and autonomous surveillance stations;

one or more manned B.S.D.S. consoles which display the alarms and the images transmitted from the remote stations deployed on the field and control the surveillance functions.

The mission planning section adopts an SCC to collect and merge information from sensors and messages transmitted from the mobile units acting on the field and to control the mission; this console provides all the necessary support to the operator for the situation assessment and for the planning and the definition of the mission.

The command of the integrated complex is performed through the SCC although each unit is able of an autonomous degraded operational mode. In particular, each B.S.D.S. console and control unit is able of a fully operational stand alone capability.

Both the fixed and the cellular mobile (e.g. GSM) public switched networks can be used to exchange voice, data and images over analog and digital channels according to the current standards. Transceiver units for UHF or VHF radio networks can be also foreseen as main or back up communication means. The first generation of the B.S.D.S. remote station was connected to the LOC via a bi-directional UHF data link while an SHF down link was used transmit TV and IR images to the centre.

The actual generation includes a **communication section** that adopts a data and image transmission software module that integrates state of the art protocols (e.g. JPEG and ITU-H263) for transmission of still pictures and video sequences over very low bit rate channels (less than 28.8 Kbit/s) with a time delay short enough to accomplish an interactive control of the IR and TV sensors. This module is also used to send the dynamic information (tracks, localisation messages and images) necessary to replicate the SCC presentation at a remote site (both higher commands or local authorities), assuming that a copy of the geographical data base is available there.

A proprietary Global Positioning System (GPS) software module which automatically calls and receives the position and tracks of the mobile units on the field through the cellular telephone network or a VHF data link.

In addition all common data are maneged by a **data base section** which comprises:

the main relational SQL data base of the system (maps, text and data) installed on a PC-486 server according to a client - server software architecture;

an auxiliary off-line PC terminal is directly connected to the server in order to maintain the geographical data base (import, export, updating of maps) and to analyse data automatically recorded by the system for post mission analysis and training;

a graphic printer to reproduce display tactical presentations and coloured images.

3 The B.S.D.S. complex

The B.S.D.S. complex is an autonomous and remotely controlled surveillance station based on IR technology which is used for the detection, assessment and control of the vegetation fires.

For the early detection of vegetation fires, a ground based autonomous surveillance system has interesting operational advantages; in fact, it can provide a 24 hours continuity of action, a systematic scanning of the surveillance volume and a multi-spectral detection capability. When more than one IR camera are available at different position, a simple triangulation can provide an accurate early estimation of the spot range. On the other hand, a special attention has to be devoted in order to overcome potential operational problems such as the calibration of the sensors and the rate of false alarms. During the installation phase, a detailed study of the site has to be performed in order to optimise the overall azimuth coverage of the whole system.

According to the general block diagram shown in fig. 1, the resulting B.S.D.S. Surveillance and control system located at the LOC has more than one remote and unmanned sensor stations each connected to the LOC through a public switched network or a bi-directional radio link.

The remote automatic station is equipped with some IR cameras, each of them is installed into a protecting shell. Each camera and the inner part of the shell can slew over a 180 degrees sector in the azimuth plane. The digital servo loop with optical encoders is controlled by a local PC-486/DOS computer which generates different regular scanning patterns of the surveillance volume according to the operational situation. The servo can be also manually controlled from the B.S.D.S. console located at the LOC.

All the images of the zone under surveillance are cyclically analysed so that a maximum delay of about 3 minutes between the fire ignition and the system alarm is achieved. Considering a nominal diameter of 3 meters for the fire at start, the nominal detection range of the fire is about 20 Km.

An additional TV camera in the visible band is also installed at the station to provide a panoramic view; it can be remotely controlled to slew both in azimuth and elevation and to adjust the focus and the zoom parameters. This allows the operator to perform a panoramic survey of the area as well as a narrow field of view analysis.

During the survey cycle, infrared encoded images are referred to the number of the originating camera and to the associated azimuth position. A real time image processor located at the remote site is then used to detect and locate bright spots, to reject clutter and possible false alarm and eventually to generate the alarm and call the B.S.D.S. console.

4 The IR image processing

The IR image processing provides the automatic detection and location of a fire bright spot in a complex cluttered environment, which is dependent on the types of vegetation and their distribution on land, on the sun light and on weather conditions. This function is performed by the PC-486/DOS computer located at the remote station.

The image processing is performed according to three sequential steps:

the frame processing which extracts the bright spots from a single image of the survey;

the inter frame processing which correlates the bright spots of one image with those detected from other frames preceding in time.

the environment level processing which correlates the spots with the environmental data in order to reject steady clutter sources.

In the context of the frame processing, the image is segmented into 16 square regions so that statistical local parameters such as the mean and the variance are used to compute an adaptive threshold for the bright spots extraction.

The structure of the infrared images in our environment often presents some basic large areas of different luminance, due to the non uniform sun radiation of the earth surface through the clouds, and to the different reflectivity characteristics of different zones in IR band. This fact may originate false bright spots at the boundaries of the regions due to luminance contrast. For this reason, a smoothing context dependent thresholding of the image is applied.

After this operation, some characteristics parameters, such as the area, the emitted energy and the centroid, are estimated for each detected spot according to a region growing algorithm which basically identify the connected point clusters.

A second threshold is then applied to the resulting image and the clusters which survive are extracted as pre-alarms provided by the system to the operator.

At this stage, the inter frame processing is applied; two frames corresponding to two consecutive survey cycles are compared.

First, the persistence of a detected spot is checked by comparing the distances of the centroids of all the clusters from the ones belonging to the preceding survey. If any distance lies within a given threshold, then the energies of the actual and the previous spots are compared; when the ratio of these values exceeds a given energy increase factor, then an alarm is declared. The position of the fire is estimated by mapping the azimuth and elevation measured angles into a stored 3D model of the terrain.

Both space and time parameters of the fire are compared with a set of windows identifying systematic infrared sources, such as lamps or highly reflecting surfaces. In this way, the false alarm due to static clutter sources are rejected.

The processing at the environment level takes into account geographical and meteorological information so that the position of the fire is correlated with the kind of vegetation of that area. Moreover, the behaviour of the fire can be directly related to the most effective parameters such as the B.S.D.S. measured temperature, air humidity and wind speed.

5 The Surveillance and Control Console

The SCC console is based on a PC-486 platform integrated with a specific graphic processing board for the presentation of maps and images on a high resolution display; the vector graphics and the interactive dialogue with the operator are supported by the *Windows API*. A proprietary software module integrates the raster and the vector overlays with the alphanumeric data; this design solution was necessary to assure a real time response to the graphical presentation commands of the operator (as examples: the instantaneous pan, scroll or zoom in/out of the whole picture or the instantaneous picture repositioning).

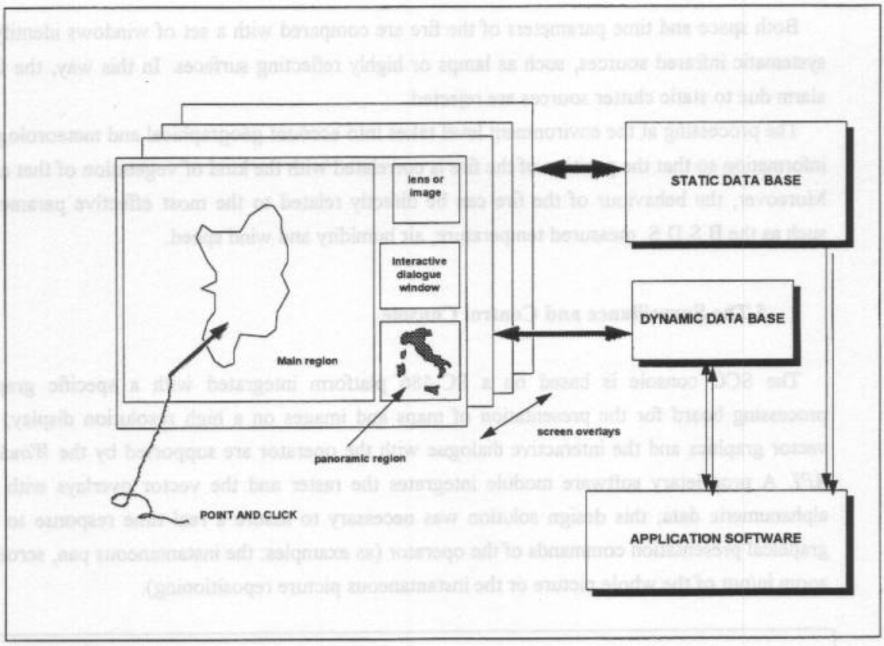

Fig. 2 - The SCC block diagram

The SCC has been designed to perform three distinct group of functions:

the man-machine interface (MMI) unit;

the data base management system;

the specific tactical function implemented through application software modules.

The MMI unit consists of a keyboard, a rolling ball or an equivalent pointing device and a wide colour display. The displayed coloured image is obtained as the superposition of different types of overlays: raster, vector graphics and symbols.

With reference to fig. 2, the display has been partitioned into four main regions:

the **main region** covers an area of 20 Km x 20 Km and is employed to monitor the evolution of tracks, to designate the geographical objects and to inquire the supporting DBMS with a rolling ball or a mouse device;

the **panoramic region** is meant to cover the whole area under the responsibility of the LOC (typically 60 Km x 60 Km);

the **interactive dialogue window** is used to access alphanumerical information of the system data base;

the **auxiliary region** can be alternatively used as **lens** for a detailed exploration of the maps displayed on the main region or to show an **image** transmitted by a remote unit pointed on the maps.

These four basic display areas are maintained fix during the whole working session in order to provide a simple, intuitive and firm man-machine interface.

To select all the available functions, two additional regions of the display areas are defined:

the presentation control region: the operator can activate or de-activate the presentation of thematic overlays on the main region through dedicated push buttons placed at the lower part of the display; additional push buttons placed under the interactive dialogue window activate:

the pan, scroll and zoom functions,

the illumination direction of the three dimensional presentation of the terrain,

some general system utilities such as the distance measurements between two points on the map of the main region, or the calculation of an area traced on the map with the rolling ball.

the applications region: it is formed by a set of push buttons placed near the auxiliary region, in the right upper part of the display which activate some specific working session beside the ordinary surveillance and control task i.e. mission planning, risk analysis, event simulation, post mission analysis and reports.

In addition to the above listed objects and regions, the display presents also the date and time, the UTM co-ordinate of the actual pointer position, a visual flashing alarm for the operator which can be also associated with an acoustic alarms, depending on the operational situation.

6 The Data Base Management

The SCC has an embedded geographical and tactical information system which has:

a "static" data base to store the land characteristics (topography, morphology of the terrain, vegetation boundaries, point and network infrastructures etc.);

a "dynamic" data base to maintain tracks, sensor operational status, meteorological data, position and operational status of each mobile unit.

More in details, the **static data base** stores the following types of information:

topography: cartography, orthophotographic maps;

terrain morphology: oreography, acclivity, versant exposition, coverage maps of the sensor placed at remote sites;

vegetation: general characteristics, specific classification of woody regions, use of soils;

mobility: roads and railways;

idrography: lakes, rivers, canals and basins;

anthropic activities: sites and types;

technological networks: electric lines, public telephone sites and lines, pipelines and water supply networks.

All the above listed thematic maps can be displayed on a 21 inch, high resolution (1280x1024 pixels) coloured monitor. At each pixel of the image the system associates the available alphanumeric data which are shown on the interactive dialogue window.

The dynamic data base maintains and records the following information:

measurements and operational status received from the remote sensor stations (B.S.D.S.);

weather measurements: temperature, pressure, humidity, speed and intensity of wind, rain precipitation, heliophany;

logistic facilities and means of intervention such as logistic sites, hospitals, airports;

operational units: actual and assigned position, operational efficiency, mission parameters.

The main general application software modules integrated in the SCC or in the server are:

the real time geographical information system (GIS) for point and click access to alphanumeric, point, vector and raster information;

the track management and presentation which includes track formation and correlation; this module monitors and displays the position of mobile units available from the sensor stations and the GPS units;

the mobility model to assess the vehicle movements rates on the terrain and the travelling time between two points on the map; areas which constitute obstacles to movement, terrain morphology and water obstacle crossing sites are taken into account;

the mission planning module to assign target geographical points and tasks to the operational units.

In addition to the above listed modules, the SCC can run some software modules which are specific for the particular application area; in the case of the fire detection and suppression task the following module have been developed:

the fire risk assessment module;

the propagation model to predict the fire behaviour as a function of the terrain and vegetation characteristics.

REFERENCES

[1] J.S. De Vries, R.A.V. Kemp *Surveillance for Autonomous Wildfire Detection,* SPIE Transactions, Orlando Florida USA, pp.1952-1958, April 1993.

[2] A. Neri, A. Laurenti, G. Pelosio *B.S.D.S.:Aan Integrated Surveillance System for Vegetation Fire Detection*, Proc. on Advanced Infrared Tecnology and Applications IROE - CNR Florence 13-14 April 1992.