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MULTI SENSOR SUPPORTED FLOOD DETECTION AND MONITORING SYSTEM FOR POLAND

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1. INTRODUCTION

Present day flash floods are calamities with the potential to produce high death tolls and huge losses of property. Although forecasting such events remains a tremendous challenge, the introduction of expert systems with observation processing, forecasting and decision making capabilities offers an optimal means of achieving this aim. This approach recognises the fact that the efficient dissemination of heavy rainfall and flood warnings to encourage a prompt response from the public and commerce is as important as the generation of reliable and timely precipitation forecasts. It is noted that warning does not eliminate flooding but allows significant reduction of damage and the saving of human life.

The July 1997 flood in Poland was one of the largest natural disasters in its recent history. Over 50 people were killed; a few tens of cities and a few hundreds of villages were inundated, and the meteorological infrastructure of the Institute of Meteorology and Water Management (IMGW) was damaged seriously. As a consequence, the World Bank has offered its assistance in order to establish a new, modern and comprehensive countrywide system to streamline and facilitate severe weather monitoring, forecasting and warning. This project, known as "*Flood Management and Hazard Reduction - Emergency Flood Recovery Project*", includes three main components. One of these components (component 'B2') is the integration of a "*Hydrological and Meteorological Monitoring, Forecasting, Protection and Warning System*". Due to the complexity and the scope of this component (managed by IMGW) nine sub-components have been defined. This paper describes briefly the design of the sub-component 'B2.9' which includes the enlargement of the existing weather radar network POLRAD, and the integration of Nimrod (Met Office, UK), a modern automated system for producing rainfall analyses and forecasts.

2. NETWORK INFRASTRUCTURE

Gematronik is the main system integrator for the new weather radar Intranet and rainfall forecast system (in co-operation with Met Office, UK). At the final project stage by end of 2003 the weather radar network will cover Poland in its entirety. In addition to two existing Gematronik C-Band METEOR 360 Doppler weather radars, six more Doppler weather radars have been purchased: three Gematronik C-Band Magnetron (METEOR 500C), and three Gematronik C-Band Klystron (METEOR 1500C) based radars. All weather radars are unmanned and remotely controlled from the Main Radar Operational Centre (MROC) in Warsaw. Each radar site possesses a UNIX based operating workstation which runs the meteorological radar product processing and display software Rainbow®. Additionally, each local operating workstation may operate as a passive radar data display without any radar control functionality, as well as a local radar control workstation providing full radar control capabilities. All weather radar sites are connected via a 64kbit/s VSAT communication link to the MROC. The MROC contains one Rainbow workstation for remote radar control of the heterogeneous weather radar network, one Rainbow workstation for radar volume processing and product generation for all eight weather radars, and two mirrored UNIX servers for the rainfall forecast processing system, Nimrod. All MROC UNIX servers are connected to the IMGW network in order to receive the necessary data fields for the radar data processing system Rainbow and for the Nimrod system. Nimrod combines radar, satellite and other observational data fields with information from a mesoscale Numerical Weather Prediction (NWP) model run by IMGW.

3. APPLICATION DESIGN

The provision of an effective and reliable data and message distribution mechanism as well as the real-time information sharing of important severe weather alerts is a crucial precondition for a multi-sensor based flood detection and monitoring system. Therefore a modern state-of-the-art communication concept has been implemented. The communication concept is called NGS (News Group Server). The NGS provides a reliable and platform independent real-time data transport between all workstations (nodes) and applications within the Polish radar Intranet. Compared with the Internet, the Gematronik NGS distribution layer is enhanced with multiple properties which are

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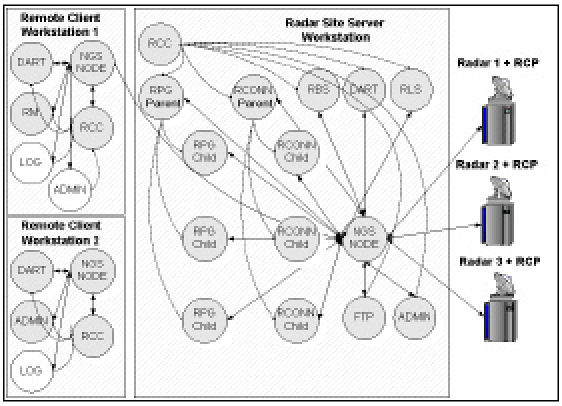
necessary for this type of application. Using this approach the NGS is a very convenient way to interconnect programs that are distributed efficiently across a sensor Intranet.

4. GENERAL RAINBOW 5 OVERVIEW

The Polish Radar Intranet will be realized using AMS-Gematronik's newest radar application software Rainbow 5. *Figure 1* shows a simplified data flow diagram of a typical radar network consisting of three radars and two clients; one control client and one display client. The Polish weather radar network will be operated accordingly but with eight radars and a decentralised radar product generation.

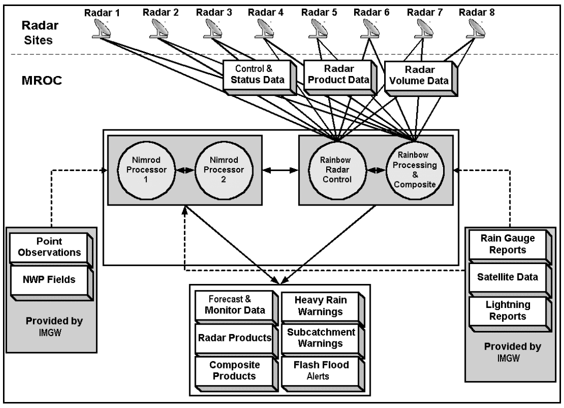
FIGURE 1



In regard to the sample network the radar site server is the main radar product generation workstation for the whole radar network. Due to the fact that the radar site server is unmanned the complete radar operation is managed remotely by other clients (in Poland installed at MROC). The radar site server establishes the connection to all radar control processors (RCPs) which run their own NGS node. Every RCP will be connected exactly to one Rainbow radar connection process instance (RCONN child). The radar connection children are managed by the RCONN master process. Each RCONN process has a connection to the NGS. The RCONN process ensures that radar requests as well as volume data slices are transferred to the radar site workstation. The product generation is handled by means of the RPG master process which creates exactly for one radar connection one RPG instance. Each RPG child generates its dedicated products and initiates the appropriate processing according to the configuration managed by the Rainbow server process (RBS). Hard disk maintenance jobs are done by means of the process ADMIN; any kind of logging messages are collected and stored by the logging server process RLS. DART can be used for radar product display and further interactive jobs like animation, projection or Z-R relationship analysis. Like the RCONN process all other processes are using the NGS node for data and file exchange. Volume data files as well as all product- and scan-definition files and products are stored for every radar in appropriate directories on the radar site server workstation. The remote client workstations 1 and 2 are used in order to configure remotely the operation of the radar site workstations. In order to create a scheduler and to define the radar product generation task the Rainbow Radar Manager (RM) is used. The Logging Client LOG is used to display and request logging information from the logging server (RLS). Like the radar site workstation all client workstations are communicating via a local NGS node.

The Rainbow control center (RCC) runs on every workstation and controls the operational status of all Rainbow processes. For an optimised usage of the bandwidth of 64kbit/s between each radar site and the MROC, a centralised and decentralised radar product generation scheme has been chosen. The radar volume acquisition provides an 'elevation slice based' design. Each radar volume file represents a composition of several elevation slices (single PPI scans) . A Rainbow pre-process provides the ability to define groups of elevations in order to create sub-volume files. This feature is used for sub-volume composition for bandwidth-optimised radar volume distribution to the MROC. Additionally radar products which are generated locally at each radar site are transferred to the MROC. Furthermore the centralised radar processing in the MROC generates composite maps of low altitude level products (Pseudo CAPPI or SRI) containing all eight radar sites. For multi-sensor supported product processing it is necessary that external sensor data like satellite, rain gauges and lightning reports are distributed to Rainbow/Nimrod. These data fields are provided by IMGW.

FIGURE 2



For the Nimrod adaptation Rainbow provides polar PPI maps (BUFR based) of the four lowest elevations in radar reflectivity of all eight radar sites. Beside that Nimrod uses point observations, NWP fields, rain gauge reports, satellite data and lightning reports provided by IMGW.

Resulting Nimrod data fields can be monitored using the HTML based Nimrod monitor pages. Additionally important data fields are exported to Rainbow and can be viewed like any other radar product within the radar Intranet using the Rainbow display application or a Web browser. Alerts and heavy rainfall warnings are shared with Rainbow and made available in the complete radar Intranet as well. *Figure 2* shows the main data flow for the Polish Radar Instranet as it is partially installed in Poland by now.

5. NIMROD OVERVIEW

The Nimrod system of the Met Office (UK) is a radar-based rainfall analysis and forecasting system. The key feature of Nimrod is that radar, satellite and other observational data are combined with information from a mesoscale NWP forecast model. This combination improves both the interpretation of the radar observations and the determination of the forecast evolution. The Polish Nimrod design comprises 11 major components. These are outlined below.

1) Processing of NWP fields: import of NWP GRIB fields and their transformation onto the Nimrod data domain and projection. The NWP data are widely utilised by the Nimrod system, for example in the correction of Meteosat satellite imagery, vertical profile correction of single site radar data, and the generation of rain analyses and forecasts.
2) Point observation processing: surface weather observations including SYNOPs, ship reports, METARs, lightning and rain gauge reports are used for a variety of purposes including radar quality control (anaprop removal), mean field bias correction of radar derived surface rain rate estimates, rain analysis generation, and the verification of Nimrod analysis and forecast products.
3) Satellite processing: Meteosat infra-red (IR) and visible (VIS) imagery are used by Nimrod for the diagnosis of cloud cover and cloud top height; the quality control and correction of radar data (anaprop removal, and vertical profile correction), and the estimation of surface rain rate beyond the range of the radar network.
4) Radar processing: Rainbow provides polar PPI maps in radar reflectivity. The reflectivity measurements are quality controlled to remove the effects of clutter and anaprop (Johnson, 1997; Johnson, 1998; Johnson *et al.*, 1998; Pamment and Conway, 1998; Smith and Kitchen, 1998). They are subject to a vertical profile correction to correct for the effects of range, brightband, and growth of rain drops below the lowest radar beam, using a physical parameterization of the vertical profile of reflectivity factor (Kitchen *et al.*, 1994). The derived near surface reflectivity is converted to instantaneous rain rate using a specified Z-R relationship. Finally, a rain gauge based mean field bias correction is applied the surface rain rate field (Hacket and Kitchen, 1995; Gibson, 2000). This last correction ensures that radar derived surface rain rate estimates are consistent with those measured by gauge, since both data sources may be used in the same rainfall–run-off models. The vertical profile correction scheme also computes, theoretically, the maximum range that each radar can detect rain (Kitchen *et al.*, 1994). The resultant Area of Radar Coverage (ARC) limits the maximum useful range of radar data employed for surface rain rate estimation. Beyond the ARC, surface rain rate estimates are derived by correlating the radar derived rain rate estimates within the ARC with satellite data.
5) Rain analysis: a Nimrod rain analysis field is generated by blending a radar composite surface rain rate field with surface weather reports, a satellite derived rain rate field, and a recent Nimrod rain rate forecast. The blending is achieved using a 2-D variational assimilation scheme (Wright, 1994).
6) Rain forecast: rain rate and rain accumulation forecasts with a temporal resolution of 15 minutes and a range of six hours are generated. The Nimrod rain forecast scheme is object-oriented in the sense that it divides the rain analysis into contiguous clusters of wet pixels. Each object is assigned a motion vector by comparing rain objects in a pair of rain analyses generated during the past hour. Object motion vectors may either be cross correlation vectors or NWP derived wind vectors. These vectors are used to generate an advection forecast by extrapolating the motion of observed rain objects forward in time. The resultant forecast fields are blended with time synchronous NWP derived rain rate and rain accumulation forecasts to produce the final, 'merged' rain forecasts.
7) Precipitation type analysis and forecast: analyses and forecasts of surface precipitation type and snow probability with a temporal resolution of one hour are generated by considering the diagnosed precipitation rate from radar, and the temperature and humidity structure of the troposphere predicted by a mesoscale NWP model.
8) Heavy rain warnings: rainfall accumulations are generated for user specified integration periods from rain gauges, Nimrod rain analyses and forecasts (to T+3 hours) and NWP rainfall forecasts.
9) Nimrod WEB browser based monitor pages: the Nimrod monitor serves a wide range of purposes:
   - it displays the latest Nimrod data inputs and outputs
   - it displays near real-time information on the performance of Nimrod and its software components
   - it displays faults and warnings associated with missing or corrupt data inputs

- it displays verification statistics for all Nimrod analysis and forecast products;
- it provides on-line system documentation including trouble shooting information.

10) Verification of products: the performance of all Nimrod forecast products is verified routinely against:
    - persistence as represented by the latest analysis product
    - surface weather and rain gauge observations
    - equivalent NWP forecasts
11) Dissemination products to Rainbow: Nimrod products including alerts will be disseminated to the Rainbow system.

6. SYSTEM OUTPUT

Each radar site generates site-related products using radar reflectivity, radial velocity and spectrum width as well as derived products based on shear or rainfall rate. Complex meteorological patterns like severe weather, divergence, convergence or microbursts are detected and processed by the local Rainbow radar product generator. Local radar data derived products like river subcatchment accumulations and appropriate protected area warnings are generated by Rainbow as well. Additionally the centralised processing in the MROC provides mesoscale information in regard to composite maps of rainfall or overall alerts of moving dangerous regions with a significant rainfall potential. Due to the open communication all information is available within the whole Polish radar Intranet and the customer is able to adapt the data information sharing exactly to his needs. *Table 2* gives an overview of the key output information of the Flood Detection and Monitoring System for component 'B2.9'.

TABLE 2

Data Source	Product
Rainbow	**Basic products:** Plan Position Indicator, Pseudo Constant Altitude PPI, Echo Height, Maximum Product, Velocity Azimuth Display, Volume Velocity Processing, Uniform Wind Field, Shear Products **Hydrological products:** Vertical Integrated Liquid, Surface Rainfall Intensity, Long-term Precipitation Accumulation, River Subcatchment Accumulation, Point Rainfall Total **Nowcasting products:** Centroid Tracking, Rain Tracking, Interactive Storm Tracking Phenomena detection products: Microburst Detection, Divergence and Convergence Products **Warnings & Alerts:** Feature detection and warning on high reflectivity, high shear, high turbulence, high precipitation, river subcatchment alert, protected area alert, microburst alert and precursor alert
Sensor	**Multi sensor:** Meteosat-7 Integration, later MSG-1, MSG-2 Integration, Lightning Detection Integration, Rain Gauge Integration, Radar Composite Map
Nimrod	**Products:** Corrected single site rain rate data, composite rain rate, rain analysis, updated monthly rain accumulation, merged forecast of rain rate, merged forecast of rain accumulation, monthly merged rain accumulation, snow probability forecast, precipitation type analysis & forecast, **Warnings & Alerts:** Heavy rainfall warnings

7. SUMMARY

The turn-key project in Poland provides an example of a sophisticated, integrated data observing, dissemination, and processing system. This will form the basis of a reliable and robust meteorological and hydrological forecasting system. Due to the flexible communication layer in the design, sensor products and severe weather alerts will be distributed quickly and efficiently. The homogeneity of the system and modern technologies like the Client/Server and open heterogeneous distribution standards (XML), promise optimal performance. In addition to the above, it is very important not to forget that the following are also essential components of any serious disaster relief initiative:

- Warning dissemination systems
- Preparedness programs that include local citizen involvement
- Action plans for local civil authorities.

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