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CAPABILITIES AND COMPONENTS OF THE WARNING DECISION SUPPORT SYSTEM– INTEGRATED INFORMATION (WDSS-II)

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1. INTRODUCTION

The Warning Decision Support System (WDSS) was developed by NSSL in the early 1990's in order to test newly developed severe weather detection algorithms on data from the WSR-88D (Eilts, 1997). This endeavor was undertaken as part of NSSL's mission to enhance the National Oceanic and Atmospheric Administration's (NOAA) capabilities to provide accurate and timely forecasts and warnings of hazardous weather events.

The WDSS system included individual workstations for ingesting data, processing data, and the graphical display of data. Several severe weather algorithms, based primarily on WSR-88D data, were tested at several National Weather Service (NWS) Forecast Offices around the country. The efforts undertaken with WDSS were very effective in enhancing the capabilities of algorithms and applications developed at NSSL. Some WDSS capabilities were implemented in operational systems of the NWS (most notably algorithm enhancements to the WSR-88D Radar Product Generator, or RPG).

The WDSS also included rudimentary applications to integrate data from other weather sensors but was too limited in its design. The development of a "Next Generation WDSS" (Hondl, 1997) was planned to fully integrate and handle all available observational data streams and support multiple sensor application development (i.e. algorithms). A team of WDSS development meteorologists and programmers was put together to define the requirements and attributes of a new system that would be able to integrate other data sources and support the needs of the application developer. This new system was called the Warning Decision Support System – Integrated Information (or WDSS-II).

The application developers identified the following primary attributes for the WDSS-II system: 1) that it be easy to make changes and add new products and concepts; 2) that the development process be simple enough for algorithm developers of varying experience to work with; 3) that it support data integration from multiple observational sensors and systems with relative ease; and 4) that it provide a seamless path from data ingest, to data processing, to data output and display.

The WDSS-II (Hondl, 2002) system has been running at NSSL since the spring of 2001 and has been processing data from several data sources for both development and real-time applications. The NSSL WDSS-II development system has been providing products to a display workstation located in the Norman NWS forecast office.

2. CURRENT WDSS-II DESCRIPTION

The WDSS-II system is composed of LINUX-based applications that ingest multiple data streams and process the data using NSSL's enhanced severe weather detection algorithms. The WDSS-II development system at NSSL utilizes a Linux-based server that ingests data from multiple radars and other weather sensors. Data processing is also performed on this server and made available for display or algorithm development on developer workstations around the facility.

The WDSS-II infrastructure allows developers to access data from other network computers. This is beneficial to the algorithm developer since the system can be run on another computer and maintained by another person, but the developer has access to all the available data. The developer may run their algorithm and view output on their individual workstation. This significantly cuts down the resources required by the developer and still provides access to the full breadth of the data and other algorithm output.

The WDSS-II software components were developed in the Linux environment using freely available development tools. There are four main categories of the software components. The first is the ingest and processing code that reads the available data streams in their native formats and prepares them for use in WDSS-II. The second component is the data handling and management Application Programmer Interface (API) classes that allow developers to access and manipulate the various data. These data classes work the same regardless of the native format of the data. Another component is the suite of meteorological algorithms

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and applications that analyze the data and prepare information for forecasters. The final component is the display prototype that allows developers and forecasters to view raw input data and algorithm output.

a) Data Ingest

A Linux-based server is routinely ingesting data from multiple radars and other sensors. Data sets currently ingested and displayed by WDSS-II and available for application development include WSR-88D Level II, Level III products from the RPG, Terminal Doppler Weather Radar, NLDN lightning strike, Oklahoma Mesonet surface observation, GOES satellite imagery, RUC model data, and the KOUN Dual-Polarization WSR-88D data.

The NSSL development system is receiving several WSR-88D data streams via the Collaborative Radar Acquisition Field Test (CRAFT, Droegemeier, et al. 2002). These data are transmitted over the Internet using the Local Data Manager (LDM) provided by Unidata.

b) WDSS-II Programmer Interface

The WDSS-II API (Lakshmanan, 2002) supports the input/output of data in NetCDF and XML formats. These standard data formats provide a user-friendly format specification. The WDSS-II API provides convenience functions to read, process, and output data in these formats. This API is shared by the WDSS-II display such that algorithm developers may generate intermediate products and view these products with nothing more than some configuration file additions.

The WDSS-II system manages various sets of data as classes. The "RadialSet" class is used to manage polar radar data in its native coordinate system. Specific radar data characteristics (such as Nyquist velocity, range and gate spacing, and beamwidth) are stored as file attributes.

Other gridded data are managed in "CartesianGrid" and "LatLonGrid" classes. These data sets may be either 2- or 3-dimensional in nature. The "CartesianGrid" describes data that are equally spaced in the X and Y direction. The "LatLonGrid" describes data with a uniform spacing in the latitude and longitude domain.

The "DataTable" class is used to describe point data, such as surface observations, lightning data, or algorithm output (e.g. storms or circulation signatures).

An API is provided to output these data as either NetCDF (RadialSet, CartesianGrid, and LatLonGrid, WindFieldData, ContourData) or XML (DataTable) files. The API also provides the capability to compress the data files using standard Linux compression tools. The file read API is able to uncompress the data automatically.

The unique concept of the "virtual volume" has also been provided in the WDSS-II infrastructure (Lynn and Lakshmanan, 2002). The virtual volume provides the latest complete volume scan using elevation cuts from consecutive volume scans. Thus algorithms may use the latest virtual volume and generate algorithm output after each elevation cut.

c) WDSS-II Algorithms

The WDSS-II programmer interface has provided a very favorable environment for algorithm and application development at NSSL. These new algorithms are processing a wider variety of meteorological data and promise to make the application of decision support systems more robust.

The severe weather detection algorithms (the Severe Storms Analysis Program, or SSAP) from the original WDSS were ported to Linux and are capable of running in WDSS-II. Algorithms have also been developed in WDSS-II to dealias the radial velocity data and compute high-resolution Composite Reflectivity and Vertically Integrated Liquid-Water-Content (VIL) products.

Additional algorithms have been developed using the WDSS-II tools that analyze radar data and are described in more detail by Smith et al (2003). These new WDSS-II algorithms include 2-D probabilities of severe hail, hail size, and areal extent of hail coverage. These hail algorithms use the same cell-based algorithm technique of the operational WSR-88D hail detection algorithm. In addition, WDSS-II has also been used to compute radial velocity derivative products such as rotation (and shear) that may be used to identify and track circulation signatures.

Several new algorithms currently under development integrate multiple radars or other sensor data sets for display. A multi-radar version of the Severe Storms Analysis Program (MRSSAP, Stumpf, 2002) has been developed and is capable of computing storm location and hail detections using data from several radars. A technique is under development to merge data from multiple radars into a single 3-D composite product (Lakshmanan, 2003b).

The K-means and storm motion estimation techniques (Lakshmanan, 2003a) have been developed using WDSS-II and are capable of ingesting either radar or satellite data. The K-means algorithm is a statistical technique that identifies and groups areas of similar statistical characteristics. These groups may then be tracked to identify the motion of the features. The motion estimates may then be used to advect the original (or other) fields to make a forecast of the future radar or satellite field.

d) WDSS-II Display Capabilities

The WDSS-II display was implemented using the OpenGL graphics library. It provides an earth-centric, 3-D display capable of displaying data from multiple sources/sensors and processing algorithms. Geographical data and information (e.g. maps) are stored as standard shapefiles. The WDSS-II display handles the synchronization of multiple sources by keying off the data time.

In the display, each data source is unique and handled separately from other sources. (A source may be a particular radar, other observational system, or output from the developer's own algorithm.) All data from multiple sources may be viewed simultaneously in the display. The user may elect to hide individual sources or only display one source at a time. The system infrastructure automatically notifies the display when new products are generated so that it may display the latest product.

The WDSS-II infrastructure currently supports several types of meteorological data including polar format radar data, Cartesian 2-D and 3-D grids, and a latitude/longitude –based grid. In addition, the display handles data in tabular text format (using XML) and icon overlays (with user configurable icon descriptions). The display of trends and time-height trends has also been established within WDSS-II to display algorithm output.

The display utilizes the virtual volume for radar data (Lynn and Lakshmanan, 2002) such that the user may navigate through a radar volume and display data from any elevation angle. The virtual volumes and 3-D grids allow the generation of cross sections from the radar volume. Then, using the 3-D, earth-relative display the user can fly through/around the radar cross section.

While the data is maintained in 3-D space, the WDSS-II display in not yet a fully functional 3-D graphics display. Additional capabilities to display iso-surfaces and other 3-D graphics are being investigated.

3. OPERATIONAL TESTS INVOLVING WDSS-II

Currently, the WDSS-II system is deployed at NSSL and data from the system is available to the Norman, OK NWS forecast office. The Norman NWS forecast office is also using WDSS-II to display base products and algorithm output from the KOUN Dual-Polarization WSR-88D.

A WDSS-II system has been deployed at the Jackson, MS NWS forecast office. The Jackson NWS forecast office has been using an older WDSS version and receiving data from five WSR-88D radars and processing them independently. The Jackson WDSS-II system includes the initial version of the multi-radar SSAP.

A WDSS-II system will also be installed at the Wichita, KS NWS forecast office in early 2003. The details of this deployment are still being worked out and will depend greatly on access to multiple radar data.

4. CONCLUSIONS

NSSL has developed a very robust and extremely powerful tool for multi-radar and multi-sensor algorithm development. Considerable effort was expended to develop the capabilities of WDSS-II based on earlier algorithm development needs and requirements as evidenced by NSSL researchers. The efficacy of the WDSS-II development environment is evidenced by the number and extent of prototype applications developed using WDSS-II. Algorithm developers have been able to quickly and easily generate source code to test new analysis tools and have greatly increased their productivity.

The WDSS-II system has proven to be a very user-friendly development environment and suitable for realtime algorithm testing and display. WDSS-II should be considered as a development environment for multi-sensor applications and the WDSS-II tools should migrate to operational systems with multi-sensor processing requirements.

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