WFO-ADVANCED: A NEW FSL WORKSTATION

C. S. Bullock
NOAA Forecast Systems Laboratory
Boulder, Colorado, USA

1. INTRODUCTION

The Forecast Systems Laboratory (FSL) and its predecessor, the Program for Regional Observing and Forecasting Services, have been developing and testing advanced meteorological workstations since 1979. Since 1984 much of the workstation development has focused on reducing risks associated with AWIPS (Advanced Weather Interactive Processing System), a communications and forecaster workstation system which will be deployed throughout the National Weather Service (NWS) of the United States of America. By the late 1980s the scientific workstation marketplace had evolved towards an open systems philosophy with the emergence of powerful RISC (reduced instruction set computing) workstations offered by a variety of manufacturers. These systems use some version of the UNIX operating system and X windowing system display standards. The NWS specified that AWIPS be developed in this open systems environment; the AWIPS development contractor, Planning Research Corporation (PRC), chose Hewlett Packard 9000 series equipment for AWIPS.

Recognizing this move to open systems, FSL initiated a new workstation development effort in April 1992 known as FX (FSL X-window system). This project was subsequently expanded and redirected becoming known as WFO-Advanced. WFO-Advanced is designed to support modernized NWS operations at a Weather Forecast Office (WFO). It uses the identical complement of hardware specified for AWIPS. The system includes data ingest and management (Edwards, 1996), display, automated product generation, product dissemination, and hydrometeorological applications.

WFO-Advanced combines a number of FSL developments into a single system (MacDonald and Wakefield, 1996) by utilizing multiple workspaces of the HP VUE Common Desktop Environment. One workspace is dedicated to viewing and manipulating meteorological data in traditional two dimensional (2D) perspectives. Another provides an experimental 2D grid editing system used to prepare forecasts. A third workspace can be used for 3D visualization of meteorological data and a fourth is planned for 3D editing techniques. Other workspaces accommodate a variety of non-FSL applications such as a hydrologic forecast system and NASA's General Meteorological Package (GEMPAK).

2. OBJECTIVES

The main goal of the WFO-Advanced project is to assist the NWS in deploying a viable AWIPS system in a timely manner. This is in keeping with the mission of FSL to transfer science and technology to the operational weather services. This assistance can take several forms including risk reduction activities, technical consultation, and code transfer.

A primary objective of WFO-Advanced is to develop an AWIPS-like system so that essential NWS risk reduction activities can be completed. This is a continuation of work started with the DARE (Denver AWIPS Risk Reduction and Requirements Evaluation) systems installed at Denver, Colorado and Norman, Oklahoma (Bullock and Walts, 1991). These activities have helped refine and revise the specifications for AWIPS and allowed the NWS to try out new concepts of operation before implementing them nationwide. By doing this the NWS discovers and addresses issues regarding the transition to new equipment, interfaces to other systems such as radar and automated surface stations, and new ways of performing the forecast and warning functions. WFO-Advanced will replace DARE at these two locations in 1996.

An example of a new approach to forecasting is the AWIPS Forecast Preparation System (Mathewson, 1996). In this approach the forecaster prepares a set of grids using a variety of editing tools. The grids capture the meteorologist's forecast of parameters such as temperature, wind, etc. that constitute the weather forecast. Formatting applications then create text forecasts, graphics, etc. needed by various users. This is a significant departure from the current method of forecast preparation. WFO-Advanced will allow this approach to be thoroughly tested before being implemented on AWIPS. In like manner, other applications destined for early integration on AWIPS can be tested on WFO-Advanced as a preliminary step.

As FSL develops WFO-Advanced, expertise in AWIPS technologies is also developed within the staff. This is important in order to carry out FSL's mission of transferring science and technology to operations. To do this effectively FSL must have a thorough understanding of AWIPS since it will be the operational system of the NWS into the next century. AWIPS is designed to evolve as new hardware (e.g. multi-processor systems and accelerated graphics cards) and software become available. FSL will investigate these new capabilities prior to their incorporation into AWIPS. This expertise also provides an independent perspective on AWIPS issues and enhances technical interchange between the government and PRC. For example, FSL has been active in the user interface definition being prepared for AWIPS. FSL has also provided code and information regarding the interface to the NEXRAD radar system.

3. DESIGN CONSIDERATIONS

3.1 Performance

WFO-Advanced has been designed to support an operational Weather Forecast Office. Perhaps the most stringent performance constraints arise from the severe-weather warning mission carried out by these offices. Short-fused warnings lasting less than an hour must be issued very quickly. Usually only a few minutes elapse between initial indications of the potential of severe weather and the issuance of a warning. In these few minutes forecasters must display and examine a variety of high-temporal frequency datasets including radar images. This leads to an AWIPS performance specification that a 12-frame loop of imagery (from an identified subset of images) be loaded in 4 seconds. Such performance requirements become a principal driving factor for the design.

To test the performance of WFO-Advanced and evaluate its ability to support operations, two real-time exercises were conducted in 1995 (Roberts et al., 1996). Forecasters were invited from throughout the NWS to participate in these exercises. Forecasters used the system in a simulated operational setting and produced the same set of forecasts normally produced at a forecast office. They judged the system to be very good at supporting forecast operations. They also provided a wealth of feedback and suggestions on how to further improve the system. This information is being used in the iterative development of WFO-Advanced. Such information from users is vital in developing a system that meets the needs of operational forecasters.

3.2 Product Display Flexibility

In order to meet performance requirements in previous workstations, many products were pre-generated in display-ready format. Although this approach led to faster product loading, it was inflexible. Products had to be fully specified beforehand and could not be changed. The latest scientific workstations are capable of much faster computations; they are sufficiently fast that display products can be generated at the time of the user request. This on-the-fly method allows for great flexibility in what is displayed and how it is presented. For example, when the user requests a display of gridded output from numerical weather prediction models the data are retrieved from a database and, depending on the request, various mathematical operations are performed such as advection, divergence, Laplacian, map projection transformations, etc. Also the representation (image or contour, contour interval, line type, color, etc.) can be controlled by the user with on-the-fly generation. This provides a wide variety of useful products from a basic set of data. (Default settings are provided to free the user from having to give all the details each time a product is generated.)

The design of WFO-Advanced accommodates both pregenerated and on-the-fly displays. The same algorithm which transforms the data into a displayable file can be used for either approach. In this way a dataset may initially be pregenerated if the amount of time needed to create it is too long. As workstation performance improves with new hardware, a dataset could be converted from pregeneration to on-the-fly generation. Only a table entry would need to be changed; neither the design nor would the algorithm would have to be changed.

3.3 Data Entry and Editing

On-the-fly display is an important design goal for another reason. WFO-Advanced must support the entry of forecast data via interactive graphical techniques such as the AWIPS Forecast Preparation System (AFPS). Such techniques are envisioned as the modus operandi of the future. To accommodate this fundamental shift in the way meteorologists prepare forecasts, WFO-Advanced must display data on-the-fly. As forecasters interactively edit the visual display of the data, those changes are committed back to the database, and the resulting changes rendered back to the display. In essence the display is continually recreated as data are interactively edited.

3.4 Adaptability

The design of WFO-Advanced must accommodate change since it will be the main developmental workstation for FSL for the next 5-10 years. As new techniques are developed or as new generations of workstation hardware become available, WFO-Advanced will need to adapt. For instance, the capability to display meteorological fields in four dimensions is an important addition planned for the near term. By recognizing at the outset that the system must be extensible and adaptable, design decisions can be tested against these criteria. The WFO-Advanced project employs object-oriented design techniques and the C++ language, in part because these tools lend themselves to extensibility in design and implementation.

WFO-Advanced must also be adaptable since it will likely be used at many locations supporting a variety of meteorological operations. It is being developed principally to support NWS operations at a Weather Forecast Office. By changing a few table entries, it can be configured to run at any location in the United States. It will also be used to support forecast operations at the Central Weather Bureau of Taiwan, which is collaborating in its development. Other uses being considered are weather support for air traffic control, multiple radar ingest and display system, and military weather support operations.

3.5 **Standards**

The open systems environment provides the opportunity for software to run on more than one hardware platform with only minor changes. WFO-Advanced has been designed so that with a relatively small amount of rewriting, the system could be transported to another hardware platform. Standards are followed to the extent feasible, i.e. if supported by the vendor and if they provide adequate performance. Examples of standards that are used are the Unix operating system (HP-UX), X windowing system for the display, netCDF (Network Common Data Form, from Unidata) for storage of a variety of datasets, WMO data format decoders (most of the data are received in grib and BUFR), Motif-like user interface, and Common Desktop Environment (HP VUE).

Object oriented design and programming also allows for the encapsulation of system features that are likely to change or vary between systems. Implementation details, such as how the system implements graphic overlays or how data are stored, can be hidden from other software modules. Through careful design and implementation, software modification has been limited to relatively few modules in order to port the software to another hardware platform.

4. USER INTERFACE

Historically, the user interface is an area that has received careful attention in workstations developed at FSL. Our experience with operational workstations has shown that users will not fully exploit a system if the user interface is difficult or time consuming to navigate. This is true even if the data and capabilities of the system are very powerful and useful. Typically in such an environment users learn a few basic commands and content themselves with those basic capabilities. Recognizing that the user interface is a key factor in the success of an operational workstation, FSL developed a graphical user interface in the early 1980s which has evolved as datasets and workstation capabilities increased in number and complexity.

4.1 **Multiple Windows**

A Motif graphical user interface is standard in current workstations. However, there are significant differences between the typical desktop environment characteristic of general use workstations and the peculiar needs of an operational forecast workstation. In the typical desktop environment there are multiple windows, but each window is used for a different purpose. One may have a spreadsheet, another a word processor, a third may be used for E-mail or communications, etc. WFO-Advanced has multiple windows, but they all may be used simultaneously to display meteorological data such as images and graphics. In the first case, the data used in a window and the controls used to manipulate the data are different since each window has a different purpose or use. In an operational forecast workstation, most of the data selection and control menus for the various windows are identical. A single set could be used for all windows, or each window could have its own set.

The two dimensional viewing part of WFO-Advanced utilizes only one set of menus to control what is displayed in 5 window panes in the display area, one large pane (920 x 920 pixels) with 4 small panes (230 x 230 pixels) stacked vertically along the left side. This tiled display approach was chosen after experimenting with other options. Menu selections apply only to the large pane. The contents of the large pane can be swapped into any of the four small panes where the data remain (and are updated as new information arrives) until swapped back into the large pane. Thus through the ability to swap between large and small panes, products can be loaded into all the panes. The panes are fixed in size and location so that they do not overlap one another. This approach allows for a simpler user interface while still providing much of the functionality of multiple display windows. Forecasters who participated in the real-time exercises found this user interface to be very effective, even those who thought a priori that this approach would be too inflexible. This approach greatly reduces window management chores.

4.2 Quantity of Data

Another important difference between an operational forecast workstation and a typical desktop system is the quantity of data. Many thousands of products are available for display. A typical hierarchical menu limited to just 20 or fewer choices is not a viable solution for providing access to such an array of data. A special browser menu has been developed for WFO-Advanced that provides access to the thousands of fields that can be generated from numerical model output.

In order to make the selection mechanism tractable for this large number of products, WFO-Advanced provides appropriate defaults based on the needs of the operational forecasting environment. For example, loops are automatically loaded when products are selected. If the product is an observation, the number of versions corresponding to the desired loop length are loaded with the most recent version at the end of the loop. If the product is a forecast (such as 500 hPa height forecasts out to 48 hours from an NWP model), then a sequence of forecasts (6 hour, 12 hour, 18 hour, etc.) out to the latest forecast period is loaded. This default behavior occurs automatically without requiring that the user specify all of these parameters. This simplifies the user interaction required to load products. In addition to the default loading behavior, other ways of loading products are also available permitting the user to specify these parameters if desired.

4.3 **Interactivity**

A third important difference between the typical desktop environment and a meteorological workstation is the amount of interaction that occurs once data are displayed. WFO-Advanced uses a special keypad to facilitate the high level of interaction required. Meteorologists frequently overlay products and turn them on and off in different combinations. Typically users load a time sequence of products on the display then alter the animation rate manually or step through individual frames of a loop. During an 8-hour shift such manipulations take place literally hundreds of times. A separate keypad is provided which has keys for the most commonly used interactions such as toggling graphic overlays on/off, stepping, etc.

New techniques such as the AWIPS Forecast Preparation System are highly interactive. A variety of tools must be employed to facilitate this process of graphical entry of forecast data for a variety of weather parameters. Editing tools include contour editing by redrawing contour lines, specifying areas, assigning values, incrementing and decrementing values, smoothing gradients, etc. This level of interactivity is more akin to CAD/CAM design. This is an intensely interactive environment that requires special design considerations to accommodate the forecaster. In such an environment, efficiency is paramount.

5. SUMMARY

FSL has developed a new meteorological workstation/system in an open systems environment. WFO-Advanced is based on NWS requirements for the AWIPS system. It is designed to meet the high performance demands of an operational forecast office with severe weather warning responsibility. It combines several FSL developments providing new capabilities (AFPS, 3D visualization and editing, etc.) beyond the traditional workstation. As the principal workstation system for FSL for the next 5-10 years, it is flexible and extensible to accommodate future development and deployment at a variety of locations.

6. REFERENCES

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