KHOROS:
AN ENVIRONMENT FOR INFORMATION PROCESSING, DATA VISUALIZATION, AND SOFTWARE DEVELOPMENT

THE KHOROS PROJECT

The main goal of the Khoros software project is to create and provide an integrated software development environment for information processing and data visualization. The Khoros software system is now being used as a foundation to improve productivity and promote software reuse in a wide variety of application domains. A powerful feature of the Khoros system is the high-level, abstract visual language that can be employed to significantly boost the productivity of the researcher.

Central to the Khoros system is the need for a consistent yet flexible user interface development system that provides cohesiveness to the vast number of programs that make up the Khoros system. Automated tools assist in maintenance as well as development of programs. The software structure that embodies this system provides for extensibility and portability, and allows for easy tailoring to target specific application domains and processing environments.

OVERVIEW

The Khoros system integrates multiple user interface modes, code generators, instructional aids, data visualization, distributed computing and information processing. The result is a comprehensive tool for computational research and development. The Khoros infrastructure consists of six major subsystems:

(1) A high-level visual language that may be extended to fit the application domain.

(2) A user interface development system consisting of a User Interface Specification (UIS) and code generators that use the UIS to generate code for all programs created under the Khoros system.

(3) An interoperable data exchange format (VIFF) supported by a comprehensive automatic storage conversion library.

(4) Application specific data display and processing libraries; image processing, digital signal processing, numerical analysis, data and file conversion, graphics display, and image display.

(5) A set of interactive X Windows-based programs address such areas as image display, colormap manipulation, animation, plotting, warping of image data, and surface visualization.

(6) A set of meta-system calls provide a foundation for distributed computing and efficient data transport. Khoros provides user selectable compute locations via the visual language, computer supported cooperative work via a distributed X mechanism, and remote access to data via a distributed data transport server.

The software structure that embodies this system provides for extensibility and portability, and allows for easy tailoring to target specific application domains and processing environments. Khoros is a successful demonstration of how research programming, application programming, information processing, data visualization, instruction, documentation, and maintenance can be integrated to build a state-of-the-art software environment.

THE VISUAL LANGUAGE

The visual language of Khoros, **cantata**, is a graphically expressed, data-flow oriented language. The user builds a **cantata** application program ("workspace") by connecting processing nodes ("glyphs") to form a data flow graph. Glyphs are selected from the many library routines available with Khoros; the user may also create new library routines using the Khoros user interface development system, and make them available to **cantata**. The visual language is considered to be large-grain because each glyph represents an entire program. "Control" glyphs (providing if/else conditions, loops, etc) and a expression parser extend the functionality of the underlying data flow methodology.

Visual "procedures", each representing a segment of the network of glyphs in a workspace, can be used to add structure to the visual language and help to manage the complexity often associated with visual programming. A dynamic execution scheduler allows the user to interactively execute the entire flow graph across a heterogeneous computer network. The execution can be set to either a demand driven or data driven model depending on the application and desired level of interactivity.

USER INTERFACE DEVELOPMENT SYSTEM

The framework of every program in the Khoros system is defined by a User Interface Specification. This high-level specification is used with automatic code generators that allow Khoros programs to combine a UNIX-like command line user interface (CLUI) with an X-Windows based graphical user interface (GUI). Khoros programs can be easily incorporated into the visual language that is an integral part of the Khoros system; the use of the code generators ensures that program user interfaces and documentation are consistent and correct. In addition, the user interface development system provides a means of quickly prototyping new algorithms, encourages standard coding styles and methods, and can potentially make the user as productive in extending the system as the original programmers were in creating it. The software development tools listed below allow an end-user to act as a developer to extend the system.

Program Name	Description
preview	GUI display tool
composer	GUI editor
conductor	code generation tool for a GUI's
ghostwriter	code generation tool for CLUI's
kinstall	source configuration & management tool

The Khoros user interface development system provides features common to all applications, such as: (1) journal recording/playback & distributed user interfaces for X-Windows based applications, (2) re-arrangement of the graphical user interface without recompiling, (3) consistency of use, (4) standardized documentation format, and (5) consistent structured programming methodology and styles.

INTEROPERABLE DATA EXCHANGE FORMAT

The Khoros Visualization and Image File Format (VIFF) or data structure supports general geometric objects, multidimensional data, and a robust mapping scheme. Storage type conversion between different architecture platforms is automatically performed by the meta-system read and write utilities; for example, DEC VAX floating point data is automatically converted to IEEE format if read on a SUN computer. The consistent use of the Khoros data structure promotes an algorithm library that can be used in many disciplines and supports data exchange.

As Khoros expands, there will be a need to support a set of "standard" file formats. Currently, Khoros provides for data interchange with other systems via file format converters. Khoros supports the following file formats: TIFF, pbm, BIG, DEM, DLG, ELAS, FITS, Matlab, SUN raster, TGA, and xbm.

DATA PROCESSING LIBRARIES

Khoros includes libraries of programs that can operate on point data, one-dimensional data, two-dimensional data, multiband data or N-dimensional vector data. These operators are designed to be polymorphic, or in other words they function on bit, byte, short, integer, float and complex data types. The term also implies that the functions know to operate differently depending on the dimensionality or organization of the data.

There are two interface levels defined in the library functions in Khoros; the program or process interface and the function call or procedure interface. The program interface is determined completely by the high-level user interface specification described above. The procedure interface is currently not as well defined, but allows the procedures (functions) to be easily combined into a single program. As a note, visual programs are built by executing a set of programs using the program interface.

The libraries contain over 260 programs, in the following categories: arithmetic, classification, color conversion, data conversion, file format conversion, feature extraction, frequency filtering, spatial filtering, morphology filtering, geometric manipulation, histogram manipulation, statistics, signal generation, linear operations, segmentation, spectral estimation, subregion, and transforms.

In addition, high-level graphics and display libraries are available to those who wish to create new X-Windows based applications under Khoros. These libraries act as a "visualization toolkit" that is layered on top of Xlib, Xtk and the Athena Widgets.

Library	Description
forms	graphical user interface
utils	pop-up browsers, errors, help, etc.
gaphics	2D/3D graphics; X, Postscript, HPGL
display	image display & editing

X WINDOWS APPLICATIONS

The interactive graphical user interface programs that are part of Khoros are based on MIT X11R4 and the Athena widgets. Such applications written under the Khoros system are automatically endowed with a journal record and playback capability that is useful for demonstration and instructional purposes. Taken a step farther, the journal record/playback capability was extended to work on multiple displays simultaneously with a "distributed user interface controller". This distributed user interface empowers users to execute a Khoros application which not only will appear on multiple displays simultaneously, but which can also receive input from each of the users.

Still under development, the distributed user interface controller will provide a more sophisticated mechanism for instructional and demonstration purposes, as well as a powerful tool for a long-distance, collaborative approach to problem solving.

Program Name	Description
cantata	visual programming language
editimage	image display & manipulation
animate	image sequence display
xprism2 and **xprism3**	2D and 3D plotting packages
viewimage	surface visualization
warpimage	image registration and warping
concert	distributed user interface controller

META-SYSTEM FOUNDATION

Khoros is designed to operate and fully utilize a heterogeneous computing environment. The meta-system library provides a set of function calls that extend the standard UNIX system calls to provide a network level interface. As an example, the **kopen()** function can open a standard file on the local host as well as open access to: a remote file, a socket, shared memory, a pipe, a stream, or SUN's Virtual Memory. This simple interface provides access to network wide data transport.

The application programmer benefits from the meta-system because the task of writing distributed applications is simplified. The end user benefits from the meta-system by being able to select compute locations via **cantata** and by being able to access remote data transparently.

The careful integration of the six Khoros subsystems summarized above allow it to act as a distributed collaboration environment.

HISTORY

The Khoros project has been underway at the Department of Electrical and Computer Engineering at the University of New Mexico since January of 1987. Previously named "XVision", the project has undergone tremendous changes in focus and scope since its beginning. Originally conceived as a tool to improve the productivity of research, initial software was developed to provide a consistent command line user interface for an existing library of image processing programs. The project quickly expanded to contain an image display program, a plotting package, and code generators to automate the creation of code that was common to all programs.

A visual language was developed to provide users with a more convenient and intuitive access to the capabilities offered by the burgeoning image processing library. Other libraries were developed to address problems in digital signal processing, numerical analysis, data conversion, and remote sensing. A number of new graphical and image display packages were developed to meet the demands of the users, while the user interface development system matured in order to meet the demands of the rapidly growing project. The distributed user interface was implemented experimentally, to support the concept of groupware; reactions have been extremely favorable so far.

CURRENT STATUS OF KHOROS (Patch Level 5)

The Khoros system has been applied to a diverse spectrum of areas including medical research, ecological studies, remote sensing, virtual reality, telecommunications, and optics. The Khoros project continues to evolve as new developments occur in the continued research and development of software environments for information processing, data visualization and software development. Khoros is being used as a teaching tool at several Universities. Release 1.0 of Khoros was offered free of charge via public ftp access on May 10, 1991; updates have since been provided in patch form. Release 2.0 of Khoros is expected to be out in late 1992.

The documentation for the system is a combination of on-line help and printed manuals. The manual is made up of three separate volumes: User's Manual, Programmer's Manual, and Reference Guide. Also, journal playback files are provided to give the new user "live" demonstrations of the various applications.

Khoros currently runs on APOLLO, CRAY, DEC, HP, IBM, OMRON, NeXT, SGI and SUN platforms, and there are porting efforts for 386/486, CONVEX, DG and MacII platforms. Khoros is now available via anonymous ftp at no charge (from pprg.eece.unm.edu, 129.24.24.10, in the /pub/khoros directory), or a tape and printed documentation can be ordered for $250.00 (US and Canada) and $350.00 (International). Support is provided via both a mail user's group and USENET News in which hundreds of users are now members. For more information, send e-mail to khoros-request@chama.eece.unm.edu.