TEACHING IMAGE PROCESSING WITH KHOROS

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ABSTRACT

The Khoros scientific software environment has become a popular tool for teaching image processing. The broad scope of Khoros and the communities emphasis on collaboration have contributed to this success. This paper describes how Khoros can impact the learning process and gives an example of how it can be utilized by an instructor to enhance an image processing course. The concept of thinking of Khoros as an "Authoring System" is introduced and supported by briefly explaining the components of Khoros that make up the authoring system.

1. GENERAL OBJECTIVE OF THE KHOROS PROJECT

Khoros is a software [1] integration and development environment that emphasizes information processing and data exploration. The objective of the Khoros project is to build a complete application development environment that redefines the software engineering process to include all members of the work group, from the application end-user to the infrastructure programmer, in the productive creation of software. The Khoros environment accomplishes this objective:

- by providing a broad set of Application Programming Interfaces (API) that can be used as a source of reusable code for visual program development,
- by providing visual software development tools that can be used to quickly prototype new software and maintain developed software,
- by being portable and extensible,
- by supporting four different levels of user interaction (from unskilled end user to expert programmer),
- and by motivating a broad community to collaborate utilizing both synchronous and asynchronous exchanges of resources and knowledge.

Furthermore, Khoros is distributed via the Internet as **Free Access Software**. Source code and binaries are available throughout the world via File Transfer Protocol (ftp); it can be used by any organization, but it can not distributed for profit without a license. This method of distribution has motivated an estimated 20,000 people to use Khoros, while at the same time retaining the intellectual property rights of the developers. The developers of Khoros believe that this method of distribution is the most aggressive technique available to advance technology rapidly. User participation is critical to the evolution of Khoros and is the basis for the Khoros Consortium, a group of over 45 government and commercial organizations that oversee the technical direction of Khoros. The Khoros environment enables communication links among it's users by providing a common language platform.

Khoros has become an important environment for teaching image processing as an indirect result of the objectives of the Khoros project. In fact, if the Khoros project's objective had alternately been focused on creating a tool for teaching image processing, it would have been less successful at creating such a tool. This paper discusses this claim, provides an analysis of what has made Khoros a successful image processing teaching tool, provides an example to illustrate the use of Khoros in the classroom, and summarizes the current status.

2. PASSIVE VERSUS INTERACTIVE LEARNING

The *classic* approach used to teach image processing combines a textbook, a sequence of lectures and tests, and perhaps a project. This approach has a variety of problems:

- theory is often considered by the students as being boring
- it is a domestication process, it is static not dynamic
- hardly any exploration is possible
- no link between instruction and research is made
- there is little opportunity for self-paced learning
- difficulty for students from other disciplines to get involved

All in all, such an image processing course can be a passive experience for the student. There are a variety of activities that can be integrated with the classic approach to make the learning process more interactive: study groups, one-on-one instruction, working directly with the instructor on a project, integration of the students into research projects and involving graduate students. Khoros can be utilized in all of these activities as a conduit or connection between the instructors and students. When Khoros is used in this way, that is to develop computer based course material to enhance the learning process, it is referred to as an "authoring system".

3. KHOROS AS AN AUTHORING SYSTEM FOR IMAGE PROCESSING

An authoring system is a software system that allows an instructor (author) to create and develop instructional software. A good authoring system should be usable by non-experts, have different levels of interaction, and provide for developing individualized training material. The instructional software that the author produces should provide the student with a creative playground for asking "what if". The student should be able to pose a hypothesis, and then use critical analysis to develop an experiment to confirm the hypothesis.

The Khoros environment provides the components necessary for an instructor to develop instructional software and for the students to explore the "what if" challenge. The cantata data flow visual language, combined with the 200 image processing programs, gives the instructor a framework from which they can author abstract image processing programs. The students can use these programs to form hypothesis that relate to the theory provided by the textbook and lecture. Each aspect of the experiment can be examined and modified as the student critically analyses the results of the visual program. Thus, Khoros enables participants to design, simulate, and test new ideas and techniques in a timely fashion, minimizing the delay from concept to implementation [2].

Khoros built-in collaboration technology (on-line, off-line) supports and encourages interdisciplinary collaboration across a diverse cross section of interests and cultures. Khoros tools are automatically endowed with a journal record and playback capability that is valuable for off-line training and education. This journal record/playback facility works on multiple displays simultaneously with a distributed user interface controller. This capability permits users to execute a Khoros application on multiple displays across a computer network and receive input from the other users. This capability, still under development, provides a very sophisticated mechanism for on-line or real-time training and collaboration across geographical boundaries. The viability of the real-time collaboration technology is becoming feasible because of increases in computing performance, computer network connectivity and bandwidth. This advanced technology will lead the way to the future of research, development, and educational computing. Off-line collaboration is further enhanced via electronic mail where "workspaces" (documented application programs) can be exchanged.

4. DIFFICULTIES OF COMPUTER AIDED INSTRUCTION

An authoring system and computer aided instruction (CAI) can enhance the learning process, but it does require additional resources to make it succeed and the instructor must be willing to change their teaching approach. Some of the problems associated with CAI are:

- cost of the authoring software and associated computer hardware,
- additional class preparation time needed to become familiar with authoring system and to develop the course material,
- incompatibility with the course textbook,
- maintenance of the course material, authoring software, and computer hardware.

If the proper resources have not been allocated to incorporate CAI into the learning process, the net impact on the students can be negative.

The Khoros environment successfully addresses most of these difficulties: the initial cost of Khoros is zero and updates are provided at not cost; instructors at various sites are sharing their course material; a textbook and self study guides are being developed that integrates Khoros experiments with the theory. Further, the investment of time instructor and students put into learning Khoros has a pay off beyond the classroom.

The Khoros environment is used by a significant percentage of the image processing research community and it is used as a commercial tool to develop new software. Students that learn Khoros in the classroom often continue to use Khoros as graduate students or as professionals.

5. EXAMPLE COURSEWARE CREATED USING KHOROS

Interpolation is an important concept that can be easier understood when presented as a low pass filtering process. Fig. 4 shows a cantata workspace which, given an original image and an interpolation factor (4, in this example), generates the images shown in Figs. 1 to 3. The image is first expanded, without interpolation. The spectrum of the expanded image can be explained by the Fourier scaling property and by the spectrum periodicity. The low pass filtering can then be applied on the expanded image, resulting in four types of interpolation schemes, depending on the type of the filtering. The nearest neighbor interpolation corresponds to

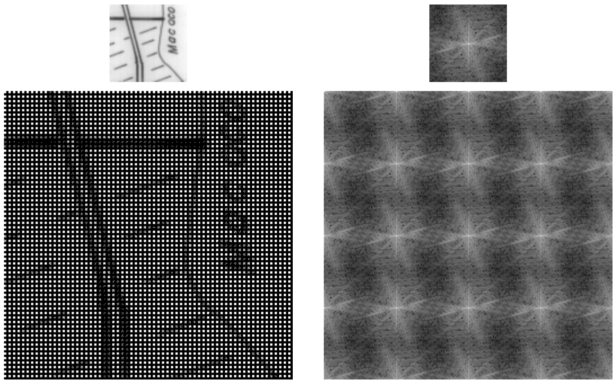

Figure 1: *First row:* Original and its spectrum; *Second row:* Expanded by 4 and its spectrum

a convolution with an average kernel. The bilinear interpolation is a convolution with a pyramid kernel. Filtering in the frequency domain with the ideal and the butterworth filtering generate two other interpolation schemes. Interpreting the spectra of each interpolation scheme helps to understand its effect on the resultant interpolated image.

This experience, applied in a classroom or in a self-study course, can be very valuable to understand and explore the interpolation concepts. It is easier for the student to change any parameter and think about its effects on the experience.

To explore the cantata environment not only as a passive demonstrator but as an active interaction between the student and the tools, the students are asked to modify the workspace so that the same concepts can be repeated in the case where the image is shrunk.

New advances in courseware using Khoros are currently being developed using World-Wide Web (WWW) and Hypertext Markup Language (html) [3]. With these Internet tools and Khoros, the users access to an on-line Digital Image Processing course with practical experiments. Besides being a Free Access course, it is the authors' desire to maintain the course from the interaction and feedback of the community.

6. STATUS, SUPPORT, DOCUMENTATION, RELEASE DATES, AVAILABILITY

The Khoros system has been applied to a diverse spectrum of applications including process control, medical imaging, automatic target recognition, sensor simulation, ecological research, remote sensing, virtual reality, geographic information systems, telecommunications,

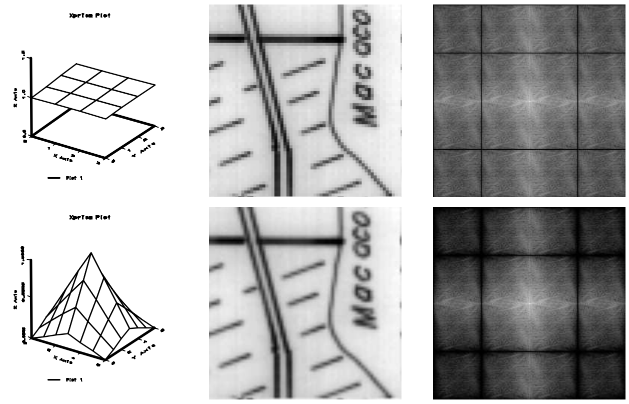

Figure 2: *First row*: nearest-neighbor: interpolation kernel, image and its spectrum; *Second row*: bilinear: interpolation kernel, resultant image and its spectrum;

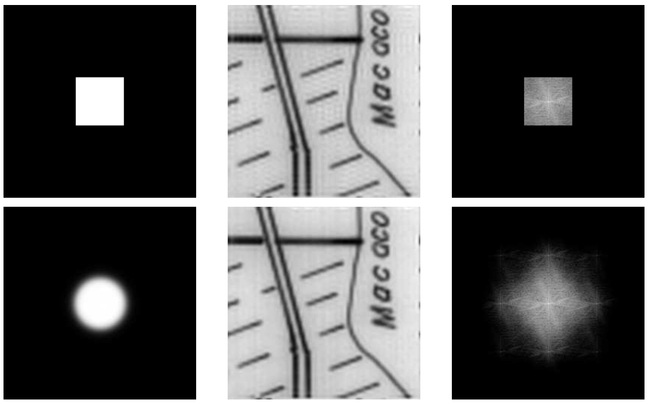

Figure 3: *First row*: Ideal interpolation: frequency mask, image and its spectrum; Butterworth interpolation: frequency mask, image and its spectrum

and scientific visualization. Khoros continues to evolve as the project introduces innovations in the areas of information processing and data management, software development, distributed computing, graphical user interface technology, and visual programming.

Khoros is being used as a educational tool around the world. It provides a framework for instruction in areas such as geometry visualization, image processing and signal processing. Khoros is accepted as a preferred environment by a large (over 45) consortium of government agencies and industry. The next major increment in acceptance of the system will come with the third-party development of commercial products based on Khoros.

Much of the success of the project can be attributed to the Free Access distribution of Khoros. The Khoros developers involve the community of users in the software development process as much as possible. Release 1.0 of Khoros was offered free of charge via public ftp access on May 10, 1991; the last update was provided March 20, 1992. The public release of Khoros 2.0 is expected to be available in late 1994.

The documentation for the system is a combination of on-line help and printed manuals. The manual is made up of six separate volumes: “Readme First”, “Getting Started Manual”, “Visual Programming Manual”, “Toolbox Programming Manual”, “Programming Services Manual”, and “Backstage Issues”. Also, journal playback files are provided to give the new user “live” demonstrations of the various applications.

For current information on what platforms and architectures Khoros runs on, and for information on how to use anonymous ftp to obtain Khoros, please send e-mail to khoros-request@khoros.unm.edu. There is also a USENET news group, comp.soft-sys.khoros, that actively discusses Khoros related issues. Furthermore, there are several World-Wide Web (WWW) home pages on Khoros in sites around the world. These sites were established and are maintained by the user community.

7. CONCLUSION

The Khoros environment has achieved some success as a tool for teaching image processing, even though this was not the primary objective of the Khoros project. This has come about as a result of the diversity of the capabilities of Khoros environment (authoring tool, research tool, built-in collaboration technology and commercial software development tool), the cost of the software, and the participation of the image processing community and other disciplines. Internet tools, like WWW, will extend the Khoros projects ability to facilitate and encourage Computer Aided Instruction.

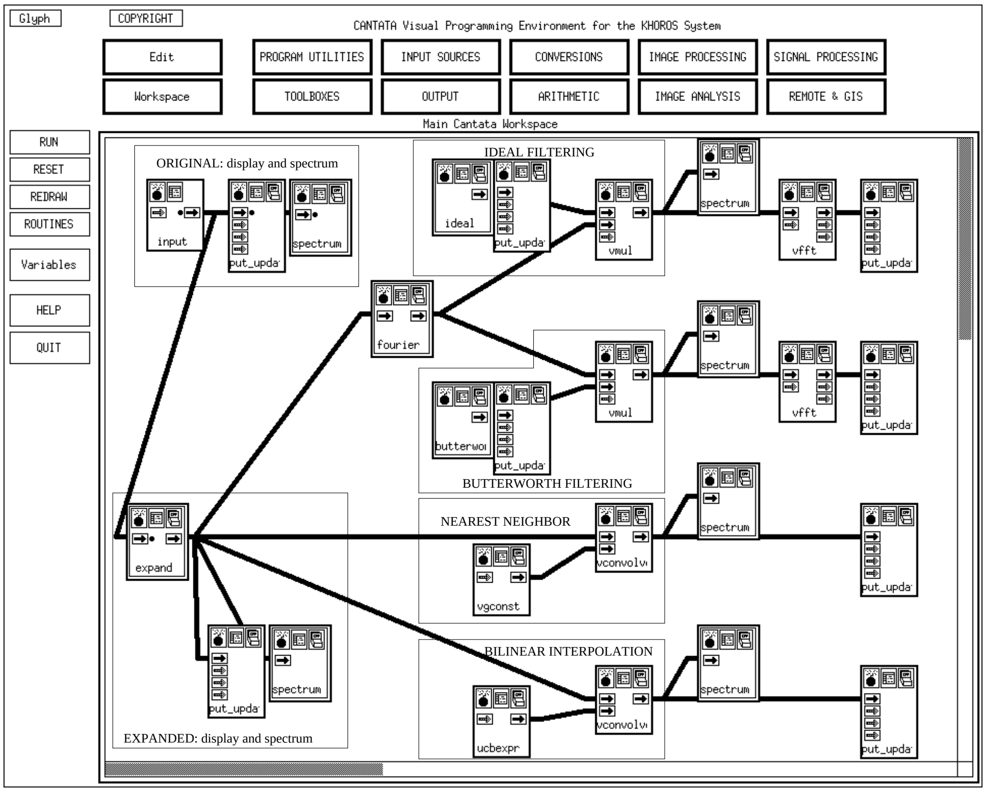

Figure 4: Cantata workspace for interpolation courseware.

In the future, interactive video and other multimedia mechanisms, as well as collaboration technology, will enhance our ability to learn and work together across geographical, temporal and cultural distances. The future belongs to collaboration and education across international borders, mediated by computers and high-speed links. Khoros has taken the initial steps toward these ambitious goals.

8. REFERENCES

[1] J. Rasure and C. Williams, "An Integrated Data Flow Visual Language and Software Development Environment", Journal of Visual Languages and Computing, pp. 217–246, 1991.

[2] K. Konstatinides and J. Rasure, "The Khoros Software Development Environment for Image and Signal Processing", IEEE Trans. on Image Processing, Vol. 3, No. 3, pp. 243–252, May 1994.

[3] R. Jordán and R. Lotufo, "Digital Image Processing with Khoros 2.0" World Wide Web (WWW) Courseware, 1994.

APPENDIX: The Meaning of the Word KHOROS

Khoros is not an acronym; rather, it is the greek spelling of the word chorus. A definition of a chorus is: *a company of singers or dancers who sing or dance in concert.* The name Khoros is symbolic of the objectives for the Khoros project and software. The *singers or dancers* are the interacting systems of Khoros; the objective is to provide a group of systems that will, when used *in concert*, provide a harmonious environment for its many different kinds of users. These same themes are expressed in the definition: *a composition to be sung by a number of voices in concert.*

A distinctly different definition of chorus, *a company of singers and dancers in Athenian drama participating in or commenting on the action*, is symbolic of the free availability of Khoros and the participation of the user community in the development of Khoros.