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Experiments with remote visual access and on-line space services

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ABSTRACT
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EXPERIMENT WITH REMOTE VISUAL ACCESS AND ON-LINE SPACE SERVICES

by

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ABSTRACT

Based on an analysis of previous telescience related activities a number of topics are discussed requiring further work from a utilization technology point of view: flexibility in data handling, remote use of high performance digital cameras, data networking and user workstations for remote operations based on visual feedback.

1. INTRODUCTION

To prepare for future Columbus utilization, the National Aerospace Laboratory NLR participated in a number of simulation activities relevant to remote operations. Interaction with crew was studied in the DAMS project (Ref. 1). Telescience was studied in various projects starting with a fluid science facility breadboard (TelePODI) and microscopy set-ups (Ref. 2). A smart telescience camera prototype was the basis for analysing remote use of high performance cameras (Ref. 3). Payload automation and robotics interaction was studied in the ARCADE project (Ref. 4). In parallel flight experience has been obtained with the Two-Phase-eXperiment (TPX), the Wet Satellite Model (WSM) experiments to prepare for Sloshsat FLEVO and remote operations for the Critical Point Facility (CPF).

Analysis of those activities from the point of view of performing remote operations (telescience) results in many technology items which can be refined in further work to prepare for Columbus operations. The long list of items includes: remote camera control, remote extraction of flow-velocity fields, remote interferometry, remote liquid handling, modelling of telemanipulation, integration of experiment knowledge and simulations, methodology for integrating remote operations in experiments, redesign of experiments and remote calibration. As visual feedback is often required in remote operations, two activities related to remote visual access (chapter 2) and on-line space services (chapter 3) are selected for presentation.

2. REMOTE VISUAL ACCESS

2.1 Flexible data handling

A number of technologies can be developed to reduce resources required during remote operations for visual feedback. A concept allowing migration of functions is introduced in the following.

A typical telesupport scenario involving visual feedback for an experiment in the CPF has been executed for IML-2 Spacelab flight in mid 1994. During this mission, real-time digital video generated in the CPF was transmitted to remote users at the National Aerospace Laboratory NLR. The processed data was used to provide feedback to the scientists located at Marshall Space Flight Center (MSFC). This allowed for improved decisions for the available time-slots involving teleoperation. The digital video data was generated by a Twyman-Green interferometer in the CPF. Using inverse multiplexing techniques, several ISDN lines were used in parallel for the remote operations project. This allowed accommodation of a data stream containing digital video data at a rate of approximately 400 kbit/s for distribution.

Improving the use of µ-g facilities has always been a main driver behind telescience. The use of leased lines was estimated to be too expensive for future uses. Therefore, application of ISDN was promoted for the project. A connection with 13 B-channels was required to encapsulate all data. Flexibility was available to work with 3 B-channels during preparation and training when video transmission was not needed. More flexibility was identified as desirable, as failure of one ISDN line would imply loss of all digital video in the high data rate configuration. During the IML-2 mission the transmission proved to be reliable. However, as became apparent during various training sessions, a more robust concept would be desirable for future operations.

To improve the robustness for future operations a concept for remote visual access is proposed which allows easy migration of image (post-)processing algorithms between the remote user location, the data distribution centers and possibly to payload data handling on-board spacecraft. The basis of a robust communication concept would be the use of remotely controlled image processing facilities. This would allow flexible adjustments to various communication constraints and allow the users to have full responsibility for the scientific processing. The remotely controlled processing can be used as a back-up or be used for sending processed results when the required communication bandwidth is not available. The distribution of processing can be adjusted to the type of mission. A cost benefit trade-off analysis involving communication costs will be a basis for allocation of processing.

With a typical algorithm for interferometry data analysis in the Critical Point Facility, only a few image lines in each image are extracted at the remote site. When sufficient lines were obtained a composition of an image was made, to analyze trends in interferometry fringe distances. The composition allowed extraction of experiment specific information (relaxation data). Such simple preprocessing could be migrated from a remote user location (a User Home Base or a User Support Operations Center) to a Payload Operations Center or even to the onboard segment. A considerable compression would be possible which would allow a basic type of operation via a low-bandwidth channel when digital video communication is temporarily not available.

For other types of remote observation (e.g. microscopy) the concept can be applied as well. For example, it proved to be feasible to implement the following low-cost scenario based on commercially available components:

1. Quick-look video can be transported via a video conferencing system based on ISDN and the H.320/H.261 standard.
2. Full quality video storage on harddisk can be realized in parallel. A second ISDN line can be used to transmit specific high-quality images. The interesting images can be identified using the real-time video.

In case of relatively short durations of a mission, uncertainties in the processing algorithms make it hard to motivate a remotely controlled image processing facility. However, this is expected to change for Space Station utilization when long duration campaigns are envisaged. The migration concept will contribute to robust operations and to cost reductions. When confidence in the algorithms increases and communication resources must be reduced, migration of processing towards spacecraft will evolve naturally.

<u>2.2</u> Improving image acquisition

Previously, in an instrument breadboard called TelePODI (Ref. 5), the following was demonstrated:

- Improvement of information presentation.
- Instrument design improvements.
- Operator support for remote control with signal delays.
- Decreased dependency on data rate constraints.
- Quick-look analyses.
- Experiment evaluation.

Standard video cameras were used for that demonstration. For future missions high performance digital cameras are envisaged allowing high datarates. This motivated the development of the Remote Visual Access (RVA) testbed (Ref. 3) under contract with ESA and the Netherlands Agency for Aerospace Programs NIVR. In the RVA project full remote control of all acquisition parameters of a high resolution (1024x1024 pixels) digital camera operating at video frame rate (25Hz) was analyzed. Remote control and smart preprocessing was motivated by the need to realize acceptable data rates at the camera front-end. Figure 1 illustrates a typical method which was demonstrated: the remote user is given a quick-look overview and is allowed to direct "region-of- interest" processing. With remotely control of subsampling, zooming and roaming the user is given opportunities to select a quick-look video for use with standard image compression.

A camera developed by Adimec Advanced Imaging Systems (Ref. 6) in the Netherlands was selected for a first validation of concepts. The camera allows high spatial resolution (1024x1024 pixels) at video frame rates. The relationship with commercial HDTV developments was envisaged to be a good basis to have a cost-effective concept for a large user community. A remote control unit was developed including the following functions: gain selection, gamma selection, integration control, different acquisition modes and a digital output generation at 40 Mbyte/s to accommodate the sensor output. A modular system (from Imaging Technology) was selected for experiments with a smart front-end processing and allowed for:

- Image acquisition at 40 Mbyte/s.
- Facilities for high performance preprocessing.
- A module for Digital Signal Processing.
- A module for analog output processing.

The RVA testbed combination allowed for:

- Control of frame rate (up to 200 Hz).
- Control of frame size (number of lines).
- Buffered modes with long integration times.
- Programming of video interfaces and overlay.
- Real-time roaming and zooming.
- DSP processing parallel to subsampled video.
- Exploration of various programming concepts.

As a first application a microscopy set-up was used to evaluate trade-offs (Fig. 2). In a second application the flexibility of the camera has been used to model the Camera and Lighting Unit for the European Robotic Arm. This involved synchronization between the camera and a

LED-based illumination source (a method often used for human posture analysis). The modular framegrabber configuration will allow for adjustments to the requirements for TeleFOTON (Ref. 7). A natural extension for further work would the use of new sensor technology allowing cost-effective manufacturing of large sensor arrays using a mosaic concept (Ref. 8). This will be a basis for affordable high resolution sensors to be used by a large user community. Moreover, a number of new technology developments are becoming available which can be used to manufacture a practical smart telescience camera for future remote operations.

3. ON-LINE SPACE SERVICES

3.1 Data networking

Evaluation of the previous experiences from a telescience point of view, motivated a number of activities related to data networking.

Networking based on the use of Asynchronous Transfer Mode (ATM) communication was evaluated as an alternative to the use of a number of ISDN lines in parallel. As part of a robotics-related demonstration (Ref. 1), remote control via ATM between NLR at the Noordoostpolder-premisses and the Delft University of Technology could be demonstrated. The remote control was based on visual feedback using 30Mbit/s bandwidth as a maximum. The experiment set-up could be realized in a short time-frame which made the approach especially promising. The uncertainties about costs of ATM-use, still make ISDN a very viable alternative for the future.

Following a general trend to include inexpensive Internet resources whenever possible, a number of activities were developed. One result was an "on-line space service" which includes references to: space-, communication- and video-related information available on Internet, laboratory facility management information and Dutch µg-experiment information. The µ-g information includes an on-line version of the Dutch Microgravity Compact Disc developed in a co-operative activity with the Dutch company Origin. Part of the information can be made available via general NLR Internet facilities (http://www.nlr.nl/).

Intranet facilities were used to allow on-line access for information about the complete chain between the remote (observation) systems and the users at a remote workstation. This included information related to: camera calibration and image acquisition, video and image conversion, image compression, satellite tracking for link-outage prediction, space communication protocols, ground communications and the remote user workstation. The development of an on-line information service was used to direct improvements related to: standardization, facilities for remote operations and facility management. Also, the use of on-line services was evaluated (Ref. 9). Potential disadvantages and problems were identified, but in general increased integration of Internet information was experienced as stimulating due to the enormous growth of available references.

3.2 Remote user workstation

Of special interest is the growth in options to realize independence of the operation system for the user interface to realize "plug-and-play" scenarios. Some experiments with remote user workstation programming are discussed in the following.

For remote user workstation programming a number of programming languages can be considered to realize improvements: Perl, C++, TclTk, and Java. Java was identified as a candidate for use in a remote operations workstation requiring evaluation. Many modern design concepts have been integrated in this language. The language allows to compile software to a binary format for easy transport via networks and execution on different platforms. Small Java-programs can be used to visualize local time for each site participating in remote operations. The potential use has been evaluated for more complicated applications by adapting and combining publically-available demonstrations. One such application involving standard image processing functions (image roaming, histogramming, edge detection, filtering) was elaborated in more detail to identify potential drawbacks. Figure 3 shows a snapshot of an image processing demonstration for interferometry data for operation from workstations available for the remote user. A number of problems became apparent such as:

- Reduction in efficiency.
  For image processing operations a considerable reduction in performance for standard pixel operations

was observed next to delays introduced in software distribution.

- Problems with robustness, maturity and security. The portability for functions involving image processing was demonstrated to be difficult when flawless execution is required on many platforms.
- Software/data protection. Reverse engineering proved to be possible which introduces complications for a large user community.

For a small closed user community a number of disadvantages identified are not important and the advantages can outweigh the efficiency problems. Moreover, improvements and alternatives with similar functionalities are becoming available.

4. CONCLUSIONS FOR FURTHER EXPERIMENTS

Simple operations in a laboratory environment prove to be more difficult when executed remotely. A number of activities to improve technology for remote operations were selected for presentation:

- Improving robustness during remote operations with a flexible communication concept (section 2.1).
- The remote use of high performance digital cameras (section 2.2).
- Integration in (public) networking environments (section 3.1).
- Realizing "plug-and-play" for the user interface at the remote station (section 3.2).

The list of technology improvements feasible for remote operations can easily be extended (see Refs. 1 to 5, 9). Therefore, cooperation options are pursued related to technology development for remote operations involving:

- Experiments using simulation set-ups.
- Modifications of planned flight experiments.

The technology experiments are motivated by a need to ensure "plug-and-play" scenarios in which most of the efforts can be concentrated on remote utilization. Technology improvements would improve user involvement by allowing remote access and are a prerequisite for maintaining and expanding user communities for the space segment.

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