Controlling telescope observations from the astronomer's own desk: the case of TNG

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ABSTRACT

High-level ground observation facilities for astronomy are located in isolated sites where atmospheric and light pollution conditions are the best possible. Normally astronomers travel to such observation sites, but in the last decade some major observatories started a remote control program on selected telescopes; more recently, the concept of allowing remote observation from secondary control centers has become a reality. The availability of bandwidth-on-demand networking services and the construction of new telescopes having integrated control systems, allow the user at least conceptually to perform observations from his own desk.

Teleoperation of telescopes is one of the topics of a project submitted to the European Union for funding and it has recently been approved: the aim is to monitor and control remotely two different telescopes located on the Canary Islands using a common system and standard ISDN services. One of these telescopes is the Italian TNG, which is discussed here as a test case. TNG has been designed and is being implemented with remote control as an essential requirement.

1. THE STATE OF THE ART IN TELESCOPE REMOTE CONTROL

In order to achieve the image quality needed for top-level research in astronomy and astrophysics, the effect of Earth's atmosphere on the observation needs to be minimized. The solutions are either to implement costly space-borne observing facilities or to install ground-based telescopes in remote regions, with low humidity, good weather conditions, and no atmospheric and light pollution: in other words, ones having "good seeing conditions". The latter has been traditionally the way astronomical observing facilities have evolved and ground-based telescopes still have a fundamental role to play in the development of human knowledge.

For the traditional astronomer to perform an observation in one of the best ground-based observatories means reaching isolated observing sites, where the observations are actually carried out, through uncomfortable trips. The availability of an advanced telecommunications technology suggests nowadays a different and more practical solution to this problem: controlling the telescopes and performing the observations remotely.

The first attempts at controlling remotely astronomical telescopes go back to the first astronomical observations from space (in the late 1960s). Up to now, remote control facilities have been implemented by providing a point-to-point connection through which the telecommands to control the basic telescope and instrument operations are sent. If the bandwidth of the communication channel is large enough, the observational data can also be sent; this is of course mandatory in the case of space-borne experiments, while it is not common practice for the ground-based observatories using remote control. A review of recent remote control experiences is given in [1]. Among these, the European Southern Observatory (ESO) is to be noted: since the mid 1980s, some of the ESO telescopes located in La Silla, Chile, can be remotely operated from the ESO headquarters in Garching, Germany and this has become standard practice [2-3].

On the contrary, the concept of distributed remote observation, *i.e.* bringing the tools to perform and control an astronomical observation to the user's site, is relatively new. In one case (from UK to Mauna Kea, Hawaii) the concept of *passive distributed observing* is introduced: standard Internet lines are used to monitor the observing activities and communicating with the local staff physically performing the observations, while no real-time activity is supported [4]. A second experiment has been tested in 1992 between the Trieste Astronomical Observatory (OAT) and the ESO facilities in La Silla, using the remote control system at the ESO headquarters as a relay. In this case, a 64 kb/s point-to-point temporary connection has been set up between Trieste and Garching to support the test, in addition to the permanent point-to-point connection between Garching and La Silla. The test system allowed the real-time control of the telescope and instrument setup and functionality and the organization of the observations from dedicated computers located at the OAT site. The different aspects of this experience have been reported in [5-7].

2. THE TNG TELESCOPE AND ITS CONTROL SYSTEM

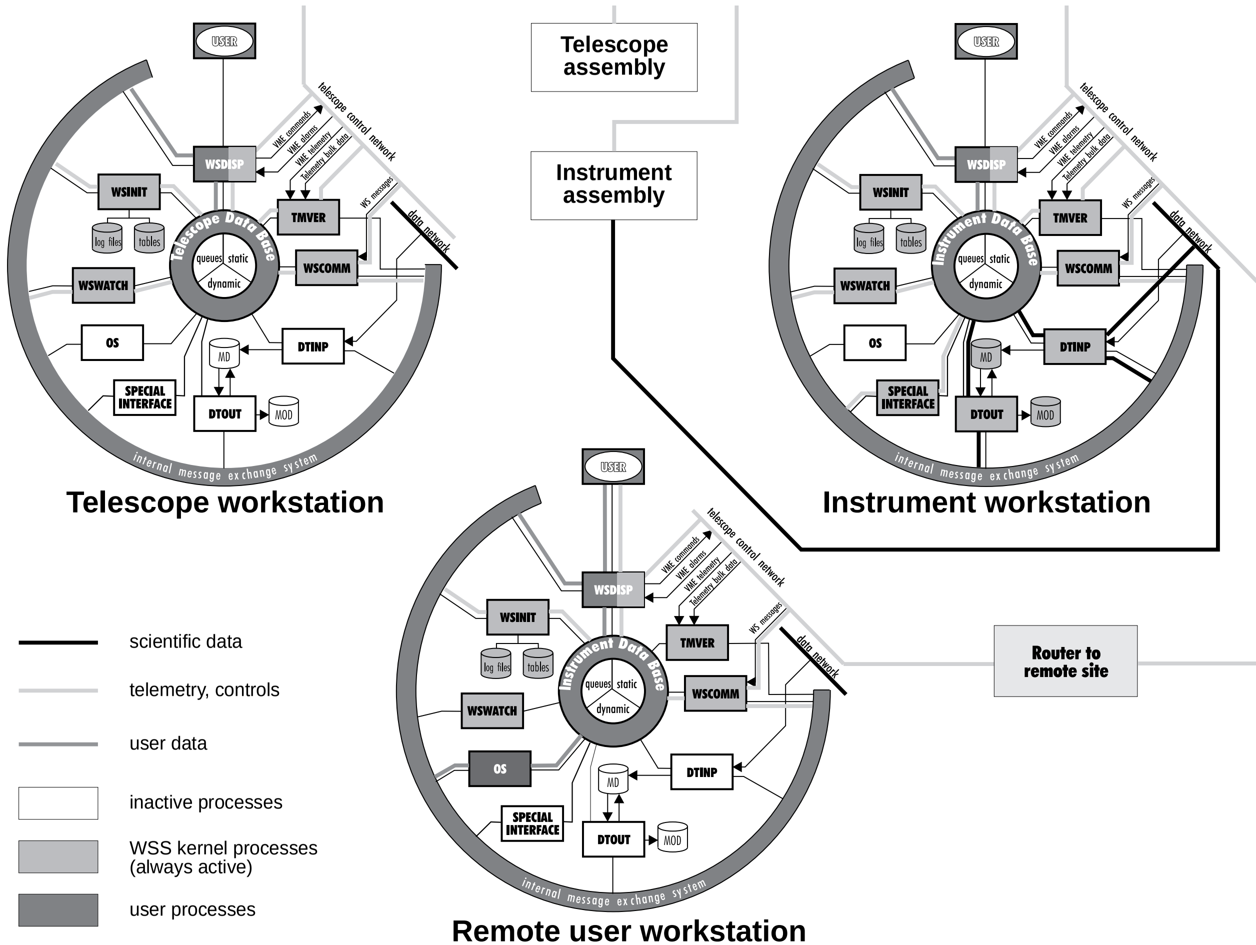
One of the first telescopes of the new generation, *i.e.* having an integrated control system, is the TNG (Telescopio Nazionale Galileo), a 3.5 m telescope which will be fully operational at La Palma at the end of 1996. TNG is being built as a joint effort of the Italian astronomical community under the coordination of the Observatory of Padua, with Prof. C.Barbieri as the Head of the project. The mode of operation for TNG is envisaged to be based on an end-to-end data flow model, and on assisted observing, with the possibility of flexible scheduling. Information on TNG and its instrumentation can be found in [8-12].

Optically and mechanically, TNG can be considered as basically derived from the ESOs NTT, while the design of its control system is new and original. The TNG control system [13] is based on a distributed computer architecture over which two main software environments are layered: the Telescope Software System (TSS) runs on the local processors for telescope and instruments, and provides the direct interface to the hardware; the Workstation Software System (WSS) runs on the control Unix workstations, monitors the TSS activities, and provides the higher-level interface for the user. The choice of using a distributed system at the local processor level maximizes the performance of the system while minimizing the cabling; at the workstation level it enhances reliability (the WSS is able to recover from failures semi-automatically, without losing control over the TSS), while allowing a multi-instrument multi-user environment.

Due to flexibility and reliability requirements, the WSS [14] has been implemented distributing both the code and the data on the workstations supporting the system at the telescope. The code has been distributed using the textual symmetry paradigm, *i.e.* all workstations run the same code but behave differently according to their startup configuration and/or to the messages they receive during operations. Data are distributed using a unique replicated data-base structure divided into a number of subsets, each maintained by a different workstation: the access to data not pertaining to the local system is guaranteed by a message exchange mechanism.

The system is designed in such a way that the physical location of the various workstations running under WSS is irrelevant. This means that remote control of the TNG is implicitly embedded in the design [7], since the control workstation running the WSS code and sharing the data base structure can either be located on the telescope LAN, or be remote connected via a bridge or a router.

The structure of the WSS is shown in Figure 1, where three workstations (the Telescope workstation, the Instrument workstation and the User remote workstation) are shown: each of them runs WSS, but some of its tasks (depicted in white) are inactive.



Telescope assembly
Instrument assembly
Router to remote site
Telescope workstation
Instrument workstation
Remote user workstation
USER
WSDISP
WSINIT
TMVER
WSCOMM
WSWATCH
OS
DTINP
DTOUT
SPECIAL INTERFACE
MD
MOD
log files
tables
Telescope Data Base
Instrument Data Base
queues
static
dynamic
telescope control network
data network
WS messages
VME commands
VME alarms
VME telemetry
Telemetry bulk data
internal message exchange system
scientific data
telemetry, controls
user data
inactive processes
WSS kernel processes (always active)
user processes

Figure 1

3. THE **“REMOT”** PROJECT

REMOT (Remote Experiment MOnitoring and conTrol) is a project recently approved by the European Union; its objective is to develop a system architecture to allow remote control of scientific experiments and facilities that require real-time operation and multimedia information feedback and using available or deploying new communications infrastructures. The availability throughout Europe of bandwidth-on-demand services allows the user to control experiments and facilities from his desk, provided that the overall system is designed with this concept in mind. The purpose of the project is to build a **generic** teleoperation system, using as much as possible available elements from other projects or off-the-shelf, together with *ad-hoc* software modules. The communications infrastructure will be IP, complemented with real-time protocols and the availability of ISDN and ATM technology shall also be taken into account. Products from the Internet domain shall be used whenever they do not conflict with real-time requirements.

Representatives from two user communities participate in the project: the astronomical community, whose top-quality telescopes are located in isolated sites to optimize seeing conditions (as discussed above) and the plasma physics community that is concentrating the experimental facilities in a few places in order to save costs. The astronomical community is represented in REMOT by an Institute operating a full-fledged observatory (the Instituto de Astrofisica de Canarias (IAC)), an Institute defining and building the control system for a telescope (the Osservatorio Astronomico di Trieste (OAT)), and an Institute representing the astronomical user (the Laboratorio de Astrofisica Espacial y Fisica Fundamental (LAEFF)), plus three additional Institutes (CDS, KIS, Lund, VILSPA) to set up requirements. TCP Sistemas y Ingenieria is associated to the project as an industrial partner.

The system will be built using a Client/Server architecture. The Client side, running at the user premises, will hold the user interface and display facilities, the commanding interface and processing and communication facilities. The Server side, located at the service provider facilities, will include the actual interface to the provider system, the processing, communication and management services and the “local operator” interface that will provide supervisory facilities together with the normal user interface. The concept of the REMOT architecture is shown graphically in Figure 2.

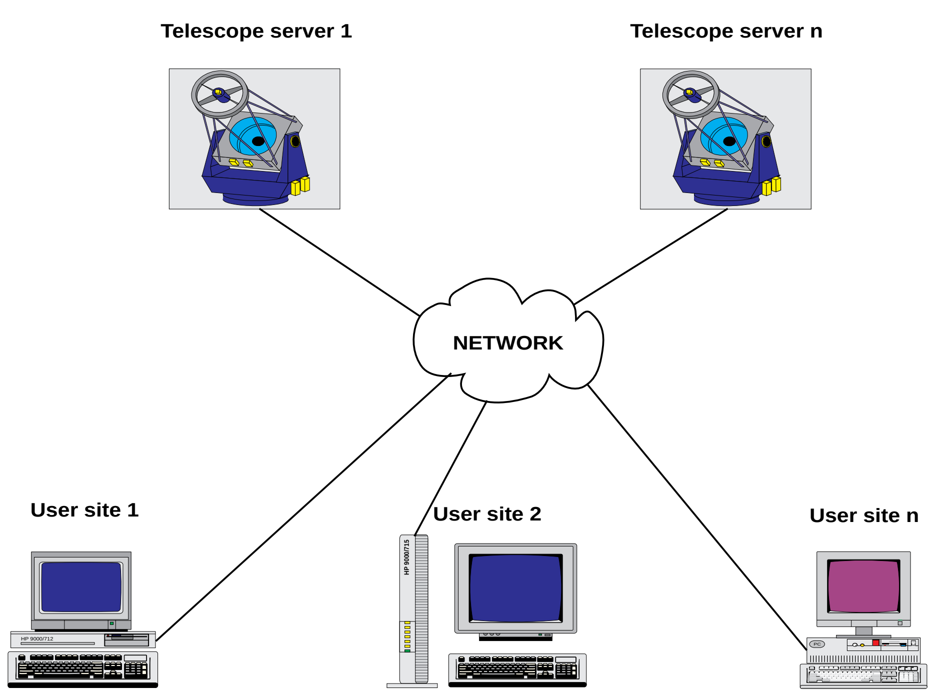


Figure 2

The services that REMOT is planning to provide as a demonstration can be roughly divided into three categories:

- **monitoring activities**, aiming at following the basic operations to be held at the telescope, just to make sure that operations are running smoothly. No control operation is performed, therefore no real-time activity is really required; low-speed services are sufficient;
- **remote control activities**, aiming at controlling the activities of telescope and instruments, including performing real-time operations. Guaranteed bandwidth for the support of real-time operations is an absolute requirement; but the speed does not need necessarily to be high;
- **remote observing activities**, including monitoring and some of the control activities, such as the logical setup of basic modes and functions of telescope and instruments. Guaranteed bandwidth for the support of real-time is required; medium- to high-speed is needed depending on the services provided. If the transfer of scientific data files (lossless compressed) is provided, a high-speed link is mandatory.

Using the IP solution will make remote scientific activities available across a wide range of platforms and media. Low speed services will be tested over Internet, real-time services and high speed transfer services will be tested by using IP over ISDN, or possibly over ATM.

A specific point is related to the expanding WWW Internet facilities available today. They could be used to cover partially some of the services involved, especially in the field of user interfaces, as discussed in [15], probably combined with additional facilities. The possibility of including an adaptation of a WWW server and client respectively will be analyzed. Due the nature of WWW, its use for real time audio and video communications would probably be prohibitive, so this kind of services needs another types of developments and tools.

A candidate for performing real-time control and transporting real-time multimedia data (such as interactive voice and video) is the new Internet protocol RTP (Real Time Protocol). RTP is a protocol that facilitates the transport of real-time data over packet switched networks, in particular IP. Efforts have been made to make RTP transport-independent so that it could be used over AAL5, CLNP or other protocols.

The REMOT project will allow remote observations and the simultaneous use of network facilities (*e.g.* access to astronomical archives and databases for the retrieval of information and historical data) directly from the user's institute. This solution will allow the control of observations, immediate processing of acquired data and comparison with archive data to be performed in the familiar everyday working environment. There are furthermore a number of other positive impacts: the possibility of immediately processing acquired data at the user's site reduces the need for powerful computing infrastructures at the telescope; no point-to-point connections are needed and the expense of communications can be shared among all institutions using the observing facilities on a time-connected basis; expenses for telecommunications can be recovered by the individual in-stitutes from the money saved by avoiding scientists' trips to the observing facilities.

Integrating the TNG telescope in the REMOT project is conceptually simple, since the TNG control system has been designed and implemented to include transparent remote control as one of its features. As a first step, the implementation of the TNG concept on ISDN-based connections will be tested; later, an appropriate software interface between the TNG WSS and the new generalized user interface which will be provided by REMOT will be built, in order to remotely control all of the telescopes included in the project through a unique interface. In any case, the TNG project will bring its own experience to test a concept that may dramatically change astronomical observing in the future: controlling a telescope from the user's own desk.

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