

Experience in Getting Access to Remote Resources of a Complex Installation

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Abstract

The realization of the structure of a system of access to remote resources is shown through the example of a complex installation for physics research. A series of experiments serves as the basis for choosing the structures, regimes and algorithms of the solutions. Quantitative evaluations of the parameters and also possible further ways of developing the system created are given.

Keywords: Remote access, video stream, video capture, server-retransmitter, electron beam microscope-nanolithographer, compression algorithms.

INTRODUCTION

We will take the creation of a system which provides remote interaction with a complex physics installation for teaching and research purposes as an example of the approach to creating means of support for access to remote resources that has been described [1].

The installation is an electron beam microscope-nanolithographer (EBMN) Raith 150-TWO [2].

Nano engineering, which involves the manipulation of objects measured in nanometers, is one of the most promising areas in the development of science and its applications today. Teaching how to work with specialized technical equipment is an integral part of training specialists in this field. Electron microscopes and nanolithographers having high resolution are often used for forming and studying structures measured in nanometers [3-7].

Since such installations are very complicated, expensive and require special technological support, they are placed only in the properly equipped laboratories of universities and scientific-research centers.

Clearly, direct access of a great number of engineers, scholars and students to such equipment is simply impossible. The need arises for a system able to provide remote access to the resources of such an installation.

The structure of local control of the high resolution electron microscope-nanolithographer and the relations between its

components well corresponds to the general suggestions made in [1]. So one can rely on these suggestions when making project decisions.

THE INSTALLATION FOR PHYSICS

In the box of the microscope-lithographer, figure 1, there is the executive unit—vacuum system, the manipulator, the sensors, and also the control units, the adapter with the PC and the local control system based on the PC.

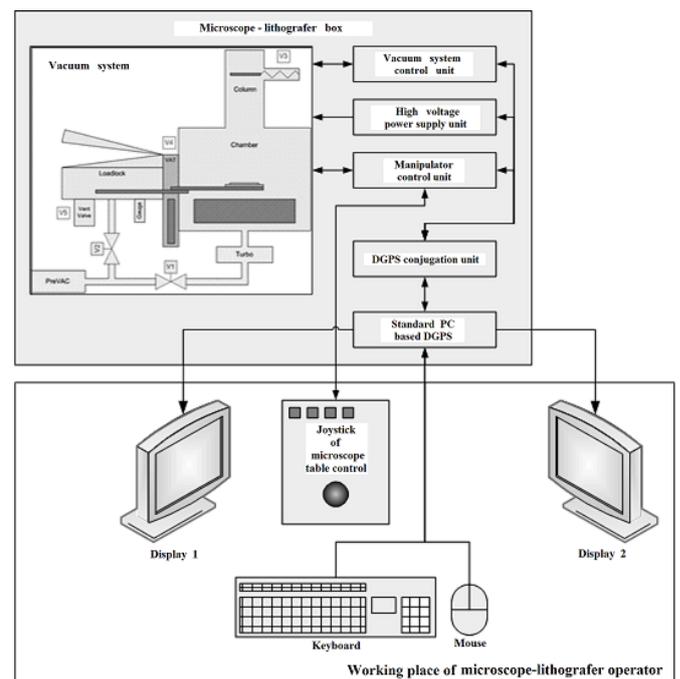


Figure 1. The structural scheme of the installation.

Hardware control units are part of the real time control system (RTCS).

The RTCS is autonomous. It is able to maintain control of the microscope even when the computer of the local control system is turned off.

This computer is also used for accumulating, processing and presenting the data collected to the user. That's why the local control system is actually a data gathering and processing system (DGPS). It's based on an IBM PC-compatible computer controlled by the OS MS Windows XP in a configuration with two displays. The second monitor is used when doing a number of additional functions of the installation.

The microscope is controlled through standard interfaces of the PC and also with the help of specialized hardware means—controlling the table of the microscope with a joystick.

The EBMN's control system's division into a RTCS and DGPS ensures:

- Preserving the normal capacity for work of the vacuum system in case of a shutdown of, damage to or glitch in the work of the DGPS.
- Protecting the expensive apparatus of the EBMN from damage if there is a glitch in the work of the DGPS software.
- Immediate shutdown of the EBMN when the emergency button shutting it off is pressed.
- Exact and safe positioning of the table of the microscope and manipulators.
- The ability to easily expand the possibilities of the EBMN user interface by a renewal of its application software.
- The ability to process the image using standard OS Windows application software like MS Paint, Adobe Photoshop, etc., right after receiving such images with the EBMN.
- The ability to prepare the nanolithographer source files and output documents using standard OS Windows application software.

The MS Windows XP Professional installed on the DGPS as the EBMN's user OS makes it possible to:

- Shorten the training time of the user since a majority of home and office computers have MS Windows OS.
- To use the handy software GUI to prepare the nanolithographer source data.
- To use application software that experienced computer users habitually process output data and prepare scientific and engineering documentation with.
- To simplify software installation and tuning. In practice such work can be done by ordinary inexperienced users.

On the other hand, the division of the control system into a RTCS and a DGPS inevitably complicates the system. One has to use a specialized hardware conjugation unit to maintain the interaction between both parts of the control system. Due to licensing considerations and the safety and security of the EBMN, such a conjugation of the RTCS and DGPS is closed off from external interference. For IBM PC-compatible computers this usually makes for difficulties when trying to use standard hardware and software means to get access to remote resources [1].

A HYBRID SOLUTION

The overall examination of the specifics of the structure and characteristics of the electron microscope-nanolithographer as well as the requirements of the teaching and research process, and the evaluation of the parameters of the mediums of transfer of the data with the results of the preliminary experiments makes it possible to stop on the variant of the hybrid solution ([1, figure 5], figure 2). Figure 2 is a simplified scheme of the realization of a system of remote access.

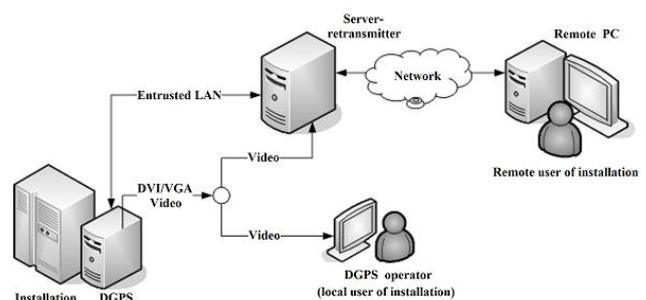


Figure 2. A simplified scheme of a system of access to the resources of an electron microscope-nanolithographer

Here we have the EBMN — the electron beam microscope-nanolithographer, the network — the medium of the transfer of data, the remote user with his PC—the student working in the multiplex regime or the teacher/researcher.

The localized user-operator of the EBMN controls it, while the two way interaction with the DGPS — perceives the content of the graphic interface and acts on its elements with the help of a mouse or keyboard. So if the picture of this graphic interface is transferred to the remote user and he is given the ability to use his mouse and keyboard for those goals, then such a remote user gets an environment for work with the EBMN.

The hybrid nature [1, 8] of the realization of this approach [1, figure 5] is manifested in the combining of the hardware type of interception of the video series, namely with the help of a

splitter and the device of video capture, with the chosen software means of remote control [9]. The latter means are for support of the interaction between the server-retransmitter and the PC of the remote user. The support of the flow of control on the entrusted LAN is realized with the use of another software means [10].

EXPERIMENTS

The preliminary experiments permitted, among other things, picking the above mentioned software means. To fix the settings it was necessary to do more experiments. They had to do with regulating the magnitude of the video stream sent through the network to the remote user with simultaneous visual evaluation of both the quality of the video series received and also its possible temporal delays.

As one of the results of the series of experiments you should get an evaluation of the flow characteristics of the Internet connection of the server-retransmitter and the remote user. Knowledge of such characteristics is necessary in order to provide minimally acceptable visual quality of the video series.

The video stream produces a temporal sequence of frames each of which is characterized by a spatial (plane) distribution of the elements of the image—pixels. The more elements, the better the definition (resolution) of the image is. Typical combinations of the number of horizontal and vertical elements are 640x480, 800x600... If it is necessary to expand the frame to fill the whole screen hardware support interpolation of the elements of the picture is used. In its turn, the amount of data necessary for describing each pixel depends on how exact the color transfer (the depth of the color) must be in showing the object. Typical values: 2^k bit/pixel, $k=0, 1, 2 \dots$ Finally, if one needs to get a true transfer of a subject that is more dynamic, the time interval between the frames must be smaller, i.e. a higher frequency of their succession should be used.

Different software means of remote control, striving to minimize the overall magnitude of the video stream, choose various ways and parameters for processing the video series taking into account the type of objects and subjects involved.

The software means selected [9] forms the exit stream only from the part of the frame that has been changed, taking into account the number and mutual arrangement of the varicolored pixels in this field, the depth of the color fixed, and also the way the data transmitted was coded/compressed. The regimes of the transmission of the color: Full colors, 256, 64, 8 colors, 8 or 4 shades of gray, black and white. The regimes of the coding/compression: RAW, CopyRect, RRE, CoRRE, Hextile, Zlib, Tight, Ultra with the possible parameterization of some of them.

To avoid undesirable manifestations of the effects of limitation of the stream when doing experiments, MEPhI 100

Mbit/sec LAN was used as the medium of data transfer (network, figure 2). The measurements were done on the server-retransmitter using standard means of monitoring of the OS Windows XP installed in it. A fragment of such a measurement is shown in figure 3.

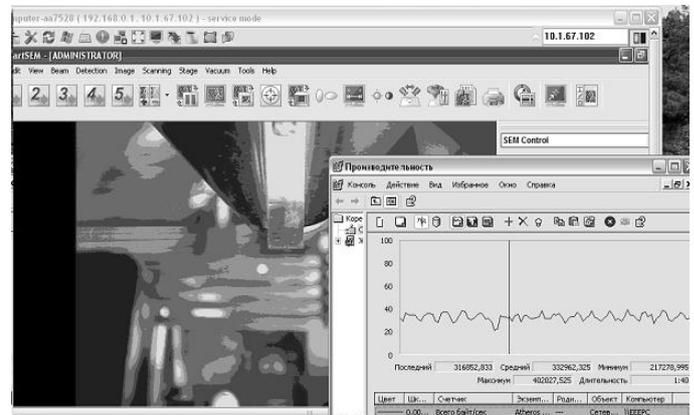


Figure 3. A fragment showing the measurements of the magnitude of the stream of data transmitted.

When doing experiments after establishing the interaction of the client-server [9] on the PC of the remote user, the EBMN regular application Smart SEM should be run in the full screen mode. This application provides graphic interface of the support of windows for observing and controlling the EBMN.

The first measurements showed that a high quality of the picture with accurate color rendering was entirely possible. This also goes for the application bar and for the objects of research in the window of the EBMN. Such quality is gotten in the Full colors regime when using any regime of compression. A frequency of capture of the frames up to 30 sec^{-1} permits following the dynamics of the subjects with insignificant delays. However, the magnitude of the stream in these measurements reached a value of 20...50 Mbit/sec, which can be considered allowable only for an enterprise's LAN, but not for the Internet.

A simple regular [9] means making it possible to lower the magnitude of the video stream is to go over to the more economic regime of color palette. Experience doing measurements has shown that using the regime of 256 colors gives entirely satisfactory quality of the picture. The results of the measurements and values given further correspond to this regime.

An important condition of doing experiments to compare and pick regimes and compression algorithms is ensuring the uniformity of the dynamics of changes in the content of the screen. This due to the presence of the merits of the compressors of the software means of remote control noted

above, namely the forming of an exit stream only from the changed screen field.

As a result, when transferring a static video picture the magnitude of the stream is insignificant and tends to go to zero. This is well visible in the graph of the means of monitoring (figure 4). In it, the moment (point B) of switching between the usual dynamic regime and the static regime when the picture from the video camera EBMN was frozen by the redrawing means of the SmartSEM window is shown.

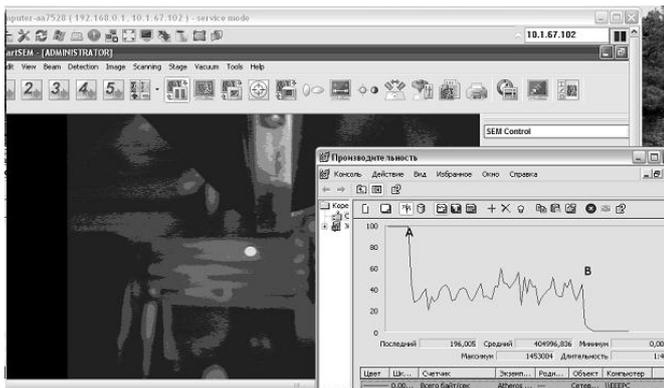


Figure 4. The magnitude of the stream of data: point

A — when switching between different compression algorithms; point B — when switching between dynamic and static regimes.

That is why using simple means of control, for example a mouse to shift windows or the keyboard to fill margins when generating a video stream is uninteresting.

In our case, the solution to the task of forming a uniform exit stream when interacting with an EBMN is made easier by the following circumstance. Namely, when using the SmartSEM with an object window of a fixed size to this window, along with a useful signal you get the high frequency electronic noise present on the CCD-sensor of the infrared video camera. Such a video camera has been put in the vacuum camera of the microscope. Other sensors of the EBMN also create such a noise. Here [11] one can find an example of a short description of the sources of noise of the CCD-sensors.

High frequency noise pollution of the frames in their succession in the absence of the correct temporal filters (integrators) leads to big changes from frame to frame. As a result such changes create significant and uniform exit streams which were just what was needed when doing the experiments. Working out such changes is complex for any compression algorithm. This circumstance provides a substantial basis for the tests of any of them conducted.

In Table 1 the minimal, average and maximum values of the magnitude of the video stream after its compression on the server-retransmitter are given. The time interval of observation for each algorithm was 100 seconds.

Table 1. Measurements of the magnitude of the stream of data

Algorithm	Magnitude of the stream of data transmitted, byte/sec.		
	Minimal	Average	Maximum
Tight9	168214	195937	256514
Tight8	172881	198724	263302
Tight7	133304	199516	268160
Tight6	166843	198661	244128
Tight5	158483	191271	297255
Tight4	171096	201066	276481
Tight3	150498	196611	295465
Tight2	156249	202574	305964
Tight1	152426	199353	257552
zlib+xor9	164273	319737	374014
zlib+xor8	217278	332962	402027
zlib+xor7	179211	322349	403457
zlib+xor6	191115	328138	389424
zlib+xor5	184021	325985	409598
zlib+xor4	151588	326005	398006
zlib+xor3	176387	321166	374999
zlib+xor2	154508	316841	384582
zlib+xor1	222351	326746	378455
zlibhex9	503584	886218	1090637
zlibhex8	539204	917765	1073085
zlibhex7	686978	939190	1069076
zlibhex6	535809	940090	1292030
zlibhex5	532539	931007	1296242
zlibhex4	462212	926542	1133003
zlibhex3	378120	939616	1214245
zlibhex2	465670	944024	1143205
zlibhex1	536426	928360	1218184
ZRLE	349043	659084	950320
ZYWRLE	411707	680836	1005661
RRE	2074672	2738319	3163832
Ultra	876619	1378695	1939715
Hextile	725943	1209669	1443998
CORRE	33210	296133	823846

In figure 5 the dependencies based on the data in table 1 are shown.

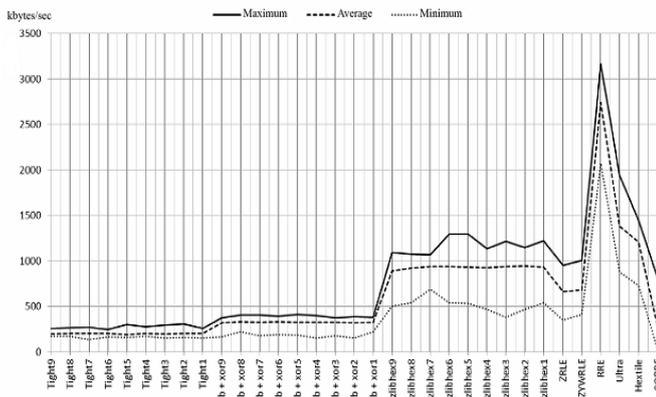


Figure 5. The dependence of the magnitude of the video stream transmitted on the chosen compression algorithm of the data.

From this graph it is clear that the most compression in the conditions described is gotten with the algorithms Tight and Zlib+xor. Moreover, the effect of the compression is practically not dependent on the parameters set. For a relatively slow internet-connection (less than 1Mbit/s) we recommend using the algorithm Tight; for faster connections one can also use the algorithm Zlib+xor.

If using regular parameters of the device of video capture, for example the frequency of the capture of the frames, it is possible to also regulate the exit stream resulting from the noise effects. However, using a frequency lower than 16 frames/second leads to visual discomfort as a result of the excessive delays observed in moving the arrow of the remote user's mouse.

The further work of the remote user when the server-retransmitter enters the Internet through MEPhI LAN, figure 6, completely confirmed the correctness of these project solutions.

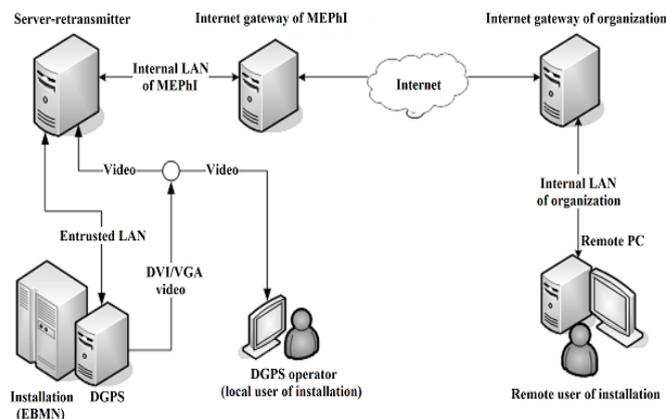


Figure 6. The network structure of the system worked out

CONCLUSION

The relatively simple hybrid solution for getting secure access to remote resources described is entirely satisfactory when the dynamics of the video series is not high, when there are limited demands on the color rendering of the objects and on the image resolution for a system with the main part of its control closed off from external interference.

Based on the results of the experiments it is possible to formulate what could still be done to improve hybrid solutions for the support of access to remote localized resources of installations like the EBMN.

One should work out/test a family of additional filters, in particular temporal low pass filters that might make it possible to get rid of the high frequency noise components of the picture transmitted. It is thought that intervals of integration up to 1/16 sec are enough for this goal. Their use makes it possible to significantly lower the magnitude of the transmitted streams without causing additional color and temporal distortions of video series with low dynamics.

A number of applications of localized resources require using multi display configurations. When working on improving the software means of remote control, hardware hybrid solutions can provide remote interaction with them, for example, in the regime of temporal multiplexing when the remote user has only one monitor. When there are insignificant magnitudes of the video streams, it could make sense to orient such improved software means on the parallel transmission to the multi display configuration of the remote user.

Certain improvements in the software means of remote control also require additional devices for entering the control information, for example a joystick, wheel, etc. Moreover, in many situations dual audio connection between the operator of the installation and its remote user would without doubt be useful.

Progress in doing this makes it possible to increase the effectiveness of the remote use of expensive localized resources of complex installations.

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