Remote control and surveillance systems that utilize virtual instrument technology, the Internet and a cellular phone

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Abstract

We have developed PC-based remote control and surveillance systems that utilize the LabVIEW-based virtual instrument (VI) technology, the Internet and a cellular phone. The main VIs we have developed are "Remote Control VI for a Mobile Robot and a Robot Arm" and "Remote Surveillance and Warning VI". In these VIs we devised a control system of mouse-clicking on camera images mounted on a remote browser. With this control system mis-operations of the VIs caused by the delay of image-communication between two remote sites can be eliminated.

1. Intruduction

We have developed PC-based remote control and surveillance systems that utilize the LabVIEW-based virtual instrument (VI) technology [1], the Internet and a cellular phone. Figure 1.1 shows the entire system composition. In this system, VIs play an important role. The VIs we have developed are listed in Table 1.1. The main VIs are "Remote Control VI for a Mobile Robot and a Robot Arm" and "Remote Surveillance and Warning VI". These VIs are remotely operated through the Internet and a specific cellular phone. In these VIs we can control the robots remotely by only mouse-clicking on camera images mounted on a remote browser. An advantage of this

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T. Nakamichi, Y. Yamada, T. Oumi, S. Sato and M. Tomihara : Graduation research students in 2005.
A. Kaneko, T. Yoshida and M. Tanaka : Graduation research students in 2004.
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control system is that mis-operations of the VIs caused by the delay of image communication between two remote sites can be eliminated.

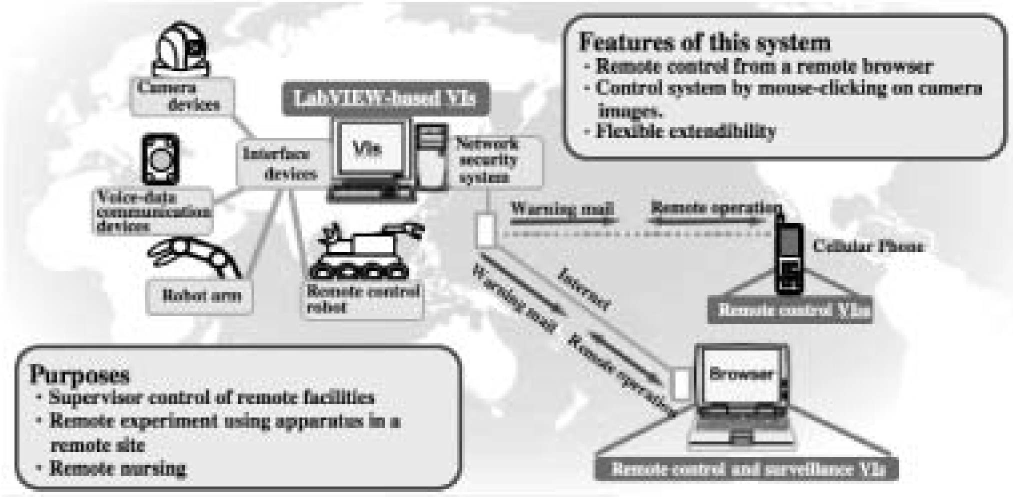


Fig. 1.1 Entire composition of remote control and surveillance systems that utilize VI technology, the Internet and a cellular phone.

A recent trend in on-line control systems is to use remote systems. The remote surveillance/monitoring and remote control systems that we have developed have the extendibility for practical use, for example, a remote nursing system, a remote experiment using apparatuses in a remote site and so on. Our control system of mouse-clicking on camera images is very useful for these remote control systems.

Developed VIs	Functions of VIs
Warning VI	This VI warns of accidents by e-mail automatically.
Remote navigation VI for a mobile robot (*control-button system*)	A mobile robot, e.g. RC tank, is remotely controlled by control-buttons mounted on a remote browser.
Remote navigation VI for a mobile robot (*camera-image mouse-click system*)	A mobile robot, e.g. RC tank, is remotely controlled by mouse-clicking on camera images mounted on a remote browser.
Remote control VI for a robot arm (*control-button system*)	A robot arm is remotely controlled by control-buttons mounted on a remote browser.
Remote control VI for a robot arm (*camera-image mouse-click system*)	A robot arm is remotely controlled by mouse-clicking on camera images mounted on a remote browser.
Camera VI for pursuing moving-objects	The camera connected to this VI pursues any moving object automatically, by an image processing. It is monitored by a remote browser.
Remote surveillance camera VI (*camera-image mouse-click system*)	The camera connected to this VI is remotely controlled by mouse-clicking on camera images mounted on a remote browser.
Voice-communication VI	Various words input from a browser are pronounced in a remote server.

Table 1.1 The developed VIs and their functions.

In sec. 2 we give an overview of our developed systems, in particular the remote control system of mouse-clicking on camera images. In sec. 3 we discuss a remote control system with a cellular phone. In sec. 4 we describe a compact system that we have developed using "Compact Vision System (CVS)" [2]. In sec. 5 we describe briefly the network security system we devised for our control system. Section 6 is for the summary. We relegate the LabVIEW programs of the developed VIs to the Appendix.

2. Control system of mouse-clicking on camera images on a remote browser

We have developed control systems that are remotely operated through an internet browser and a cellular phone. They are controlled visually by mouse-clicking on camera images on a remote browser. These systems are based on LabVIEW-based VIs. In the following we give an overview of the systems.

2.1 Remote surveillance camera VI (mouse-click control system)

Figure 2.1.1 shows the system composition of a remote surveillance camera. We can operate the camera interfaced to a server at a remote site by clicking on camera images on an internet browser. By clicking on camera images the center of the camera view moves to the clicked point.

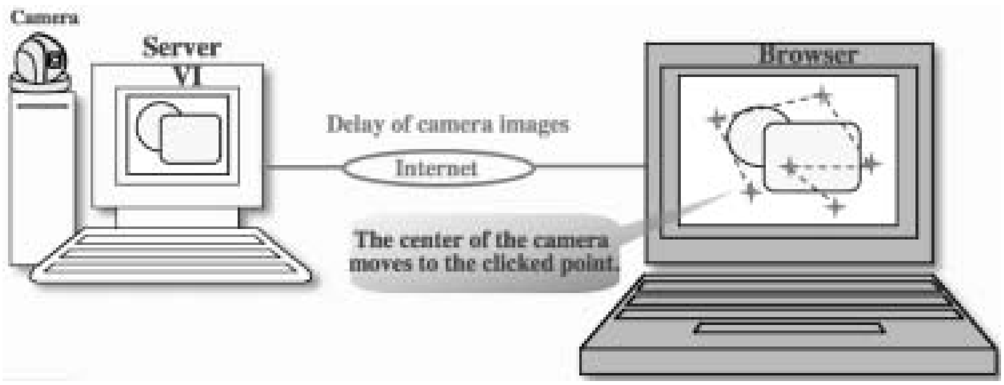


Fig. 2.1.1 System composition of "Remote surveillance camera VI (*mouse-click control system*)".

Camera images are captured through an image capture board PCI-1408 or PCI-1411 [3]. The board PCI-1408 has two channels for monochromatic images. On the other hand, the board PCI-1411 has one channel for color images. The surveillance camera is driven by two stepping motors that are interfaced to the server through a motion-control board PCI-7344 [4]. Figure 2.1.2 shows the composition of the camera interface system.

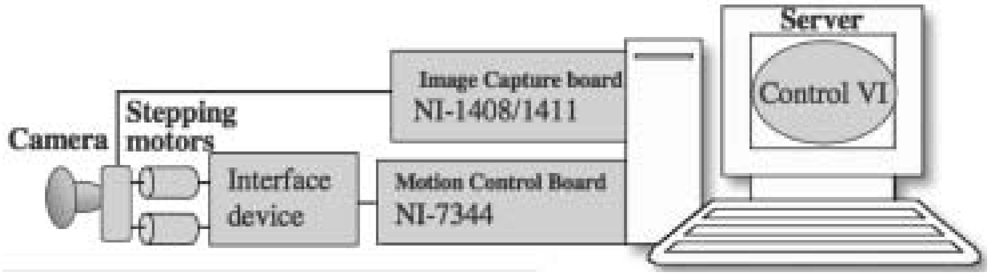


Fig. 2.1.2 Composition of the surveillance camera interface system.

We developed the VI by means of LabVIEW programming. Figure 2.1.3 shows the front panel of the developed VI. On the front panel we designed a sub-window that indicates the position of the center of the camera view graphically. When we operate the surveillance camera remotely we cannot know the present position of the camera view. The operation range of the camera is limited within the view of 120°. Therefore, in order to operate the camera well we have to know the position of the center of the camera view. The sub-window is useful for this purpose. As the block-diagram of the VI is very complicated we relegate it to Appendix A. The mouse-click system is realized by using the LabVIEW tool “Event Structure”. Figure 2.1.4 shows a scene of a test of the remote operation of the VI from a remote browser. By using this control system we can eliminate mis-operations caused by the delay of image communication between two remote sites.

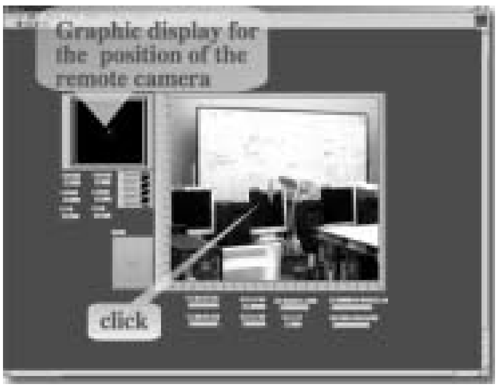


Fig. 2.1.3 The front panel of the “Remote surveillance camera VI (mouse-click control system)”. The block diagram of the VI is given in Appendix A.

Fig. 2.1.4 A scene of a test of the remote operation. The screens of the l.h.s. and the r.h.s. show the front panel of the VI on the server and a remote browser, respectively. The surveillance camera interfaced to the server can be operated from a remote browser by clicking on camera images on the browser.

We have also developed a remote surveillance camera VI of “control button system”. We relegate the front panel of the VI to Appendix B (we omit to show the block diagram). When we operate the camera remotely from a browser using this VI we are prone to mis-operations due to the delay of image-communication between two remote sites. The VI of mouse-click system is thus a very useful tool. The larger the distance between the two remote sites is, the more useful the VI of mouse-click system is.

2.2 Remote navigation VI for a mobile robot (camera-image mouse-click system; lab. fixed camera)

Our aim in developing the system is to remotely control a mobile robot that has no autonomous judgment ability. For such an unintelligent robot we used a RC tank, which is a very *cheap* toy. Figure 2.2.1 shows the system composition of the developed “Remote navigation VI for a mobile robot (camera-image mouse-click system; lab. fixed camera)”. The outline of the control algorithm is very simple and elementary. The RC-tank is controlled with only a remote radio controller (propo.). It has no autonomous ability. Therefore, in order to control the tank we first need information on the present position and orientation of the tank then information on the destination. As shown in the figure, the information is represented by two vectors $\boldsymbol{a}$ and $\boldsymbol{b}$. Once the two vectors $\boldsymbol{a}$ and $\boldsymbol{b}$ have been specified, to determine the control commands we have only to evaluate the vector product $\boldsymbol{c} = \boldsymbol{a} \times \boldsymbol{b}$. If $\boldsymbol{c}$ is down then the tank should turn clockwise and if $\boldsymbol{c}$ is up then the tank should turn counterclockwise. The rotation angle is determined from $|\boldsymbol{c}|$.

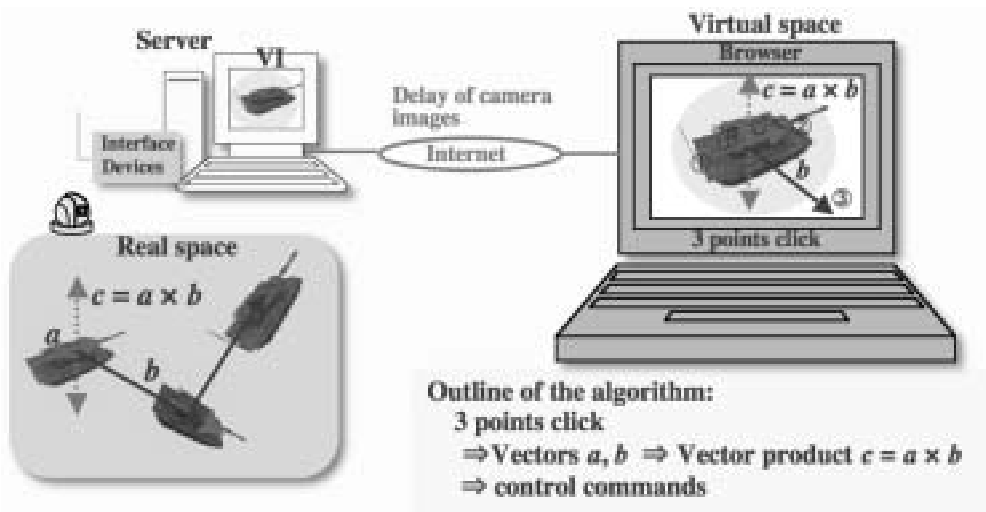


Fig. 2.2.1 System composition of “Remote navigation VI for a mobile robot (*camera-image mouse-click system; lab. fixed camera*)”.

In order to specify ***a*** and ***b*** we click on three points on camera images mounted on a remote browser, then positions of the three points are input into the VI installed on the remote server. Thus, by clicking on three points (①, ②, ③) on camera images on a remote browser we can control the RC tank remotely. Here, one may think that the clicking on three points is needed only once, i.e., only in the starting step. This is logically true. Once we have specified ***a*** and ***b*** in one step, then in the next step we do not have to specify vector ***a*** because in the next step vector ***a*** is determined by vector ***b*** specified in the previous step, namely we have only to click on one point (destination) in the next step. Thus, this system is essentially a one-point click system. Actually, however, the RC tank does not move correctly (following to the commands). This is because the movement of the tank strongly depends on the friction between the floor and the caterpillars of the tank. Therefore, in order to navigate the tank correctly we need to specify vector ***a*** in each step. In this sense, this system is a three-points click control system.

We can also operate the battery of the tank by clicking on the camera images on a remote browser. By clicking with Ctrl. key on any point we can rotate the battery of the tank clockwise or counterclockwise. By pushing the reset button “BatteryReset” attached to the front panel of the VI we can return the battery to the center. To raise and lower the battery of the tank we use Alt. key. Also we can control the tank backward by clicking with Shift key on three points on the camera images. By pushing Space key bullets are fired.

Figure 2.2.2 shows the composition of the interface system. Camera images are captured through a PCI interface board NI-1408 or NI-1411. The image data are processed by means of IMAQ Vision program. The IMAQ Vision programming tools are provided as add-on tools to LabVIEW. The virtual propo. VI on the server is a part of the control VI constructed by LabVIEW programming. This virtual propo. VI sends control commands as eight-bits characters to the interface device through a serial line. The interface device operates the real propo. in accordance with the com-

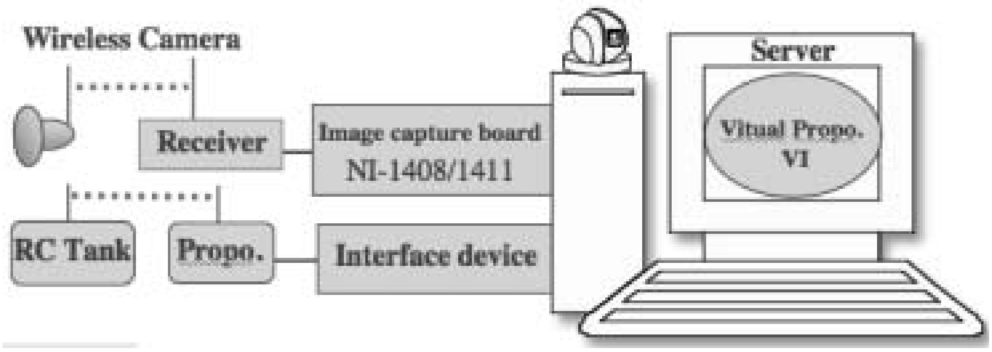


Fig. 2.2.2 Composition of the interface system. The virtual propo. VI is just a part of the control program written in LabVIEW.

mands.

In Fig. 2.2.3 we show the front panel of "Remote navigation VI for a RC tank (camera-image mouse-click system; lab. fixed camera)". As the block diagram of the VI is very complicated we give it in Appendix C. By using the LabVIEW tool "Event Structure" the mouse-click system is easily realized. Figure 2.2.4 is a scene of a test of the remote operation of the VI.

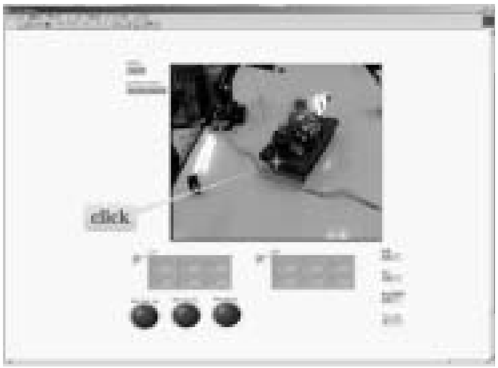


Fig. 2.2.3 The Front panel of "Remote navigation VI for a mobile robot (*camera-image mouse-click system; lab. fixed camera*)".

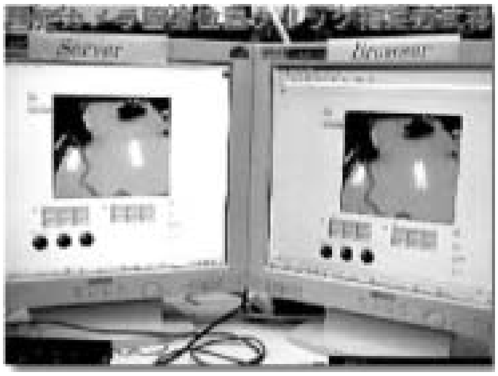


Fig. 2.2.4 A scene of a test of the remote operation. The screens of the l.h.s. and the r.h.s. show the front panels of the VI on the server and a remote browser, respectively. The RC tank interfaced to the server can be controlled from a remote browser by clicking on three points on camera images on the browser shown in the screen of the r.h.s.

We have also developed a remote navigation VI of "control button system". We show the front panel of the VI in Appendix D (we omit to show the block diagram of the VI). When we control the tank remotely from a browser using this VI we are prone to mis-controlling due to the delay of the image communication between two remote sites. Thus, the VI of mouse-click system shown in Fig. 2.2.3 is a very useful tool. The larger the distance between the two remote sites is, the more useful the VI of mouse-click system is.

2.3 Remote navigation VI for a mobile robot (camera-image mouse-click system; robot fixed camera)

Figure 2.3.1 shows the composition of the system. The interface system is illustrated in Fig. 2.2.2. In this version of the control system the camera is fixed on the RC tank itself. The position and orientation of the camera correspond to those of the tank. As seen in the figure, vector $\boldsymbol{a}$ that represents the position and orientation of the tank is always fixed to the forward in the window of camera images. We do not have to specify vector $\boldsymbol{a}$. To navigate the tank remotely we have only to specify vector ***b***, namely we have only to click one point (①) that represents the destination of the tank. This is truly a one-pint click navigation system.

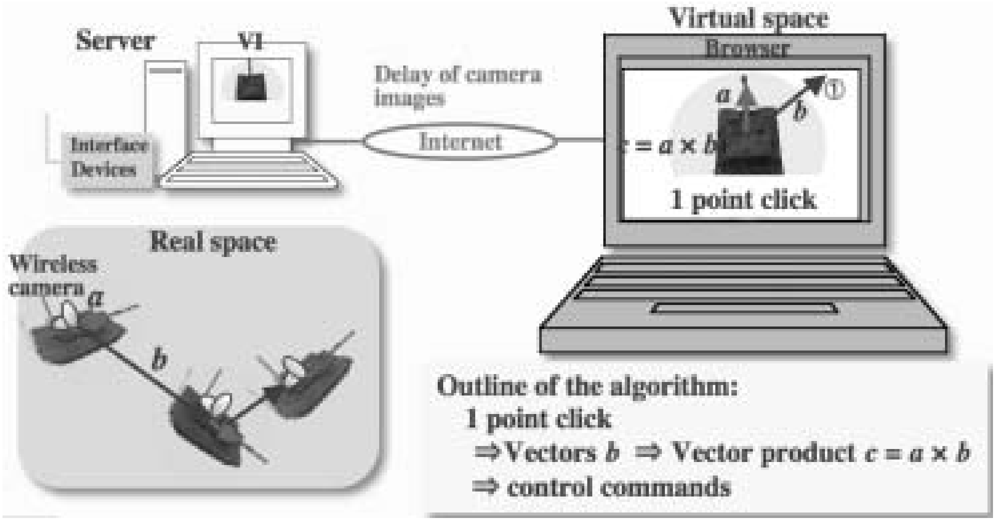


Fig. 2.3.1 System composition of "Remote navigation VI for a mobile robot (*camera-image mouse-click system; robot fixed camera*)".

We show, in Fig. 2.3.2, the front panel of our developed VI. As the block diagram of this VI is very similar to that of "Remote navigation VI for a mobile robot (camera-image mouse-click system; robot fixed camera)" we omit showing that. In this system a wireless camera is used. We can navigate the tank to any place within the range of radio waves of the wireless camera and propo. of the tank. The attainment range of the radio wave of the wireless camera can be as long as 1km. On the other hand, the attainment range of the radio wave of the propo. is at best about only 5m, which is too short. Our purpose is to navigate the tank from an end to the other of the corridor that is outside of our laboratory. For the purpose, we put a wire on the ceiling of the corridor. Figure 2.3.3 is a scene of a test of the remote control.

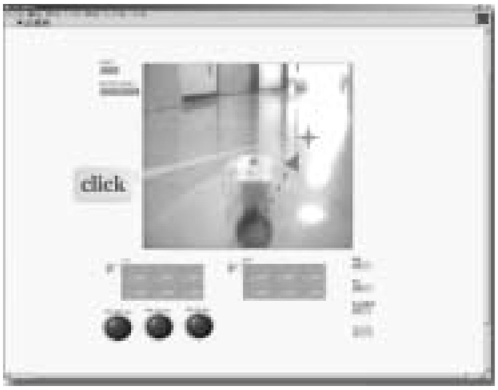


Fig. 2.3.2 The front panel of "Remote navigation VI for a mobile robot (camera-image mouse-click system; robot fixed camera)". The block diagram of the VI is given in Appendix E.

Fig. 2.3.3 A scene of a test of the remote operation. The screens of the l.h.s. and the r.h.s. show the front panels of the VI installed in the server and mounted on a remote browser, respectively. The RC tank interfaced to the server can be controlled from a remote browser by clicking on one point on camera images on the browser.

This control system is applicable to various remote control systems, e.g., a navigation of a search robot in a disaster spot. The one-point click remote navigation system that we have developed can be applied to such more practical drive systems. However, in order to make this navigation system more practical, the robot drive system must be much improved.

2.4 Remote control VI for a robot-arm (mouse-click system)

Our purpose is to develop a remote control system for a robot-arm that has no autonomous judgment ability. The composition of the system is shown in Fig. 2.4.1, where an *inexpensive* toy is used for such an *unintelligent* robot-arm. The interface system is illustrated in Fig. 2.4.2. The robot-arm has four joints. The first joint rotates in horizontal direction. The second and third joints rotate in azimuthal direction. The fourth joint rotates in a plane perpendicular to the third arm. The tips are for grasping an object. This robot-arm has no sensor. Therefore, it is very difficult, visually on camera images, to judge whether the two tips have already grasped an object. Then, we attached pressure sensors to the tips. Thus, only the grasping operation is automatically controlled with the sensors.

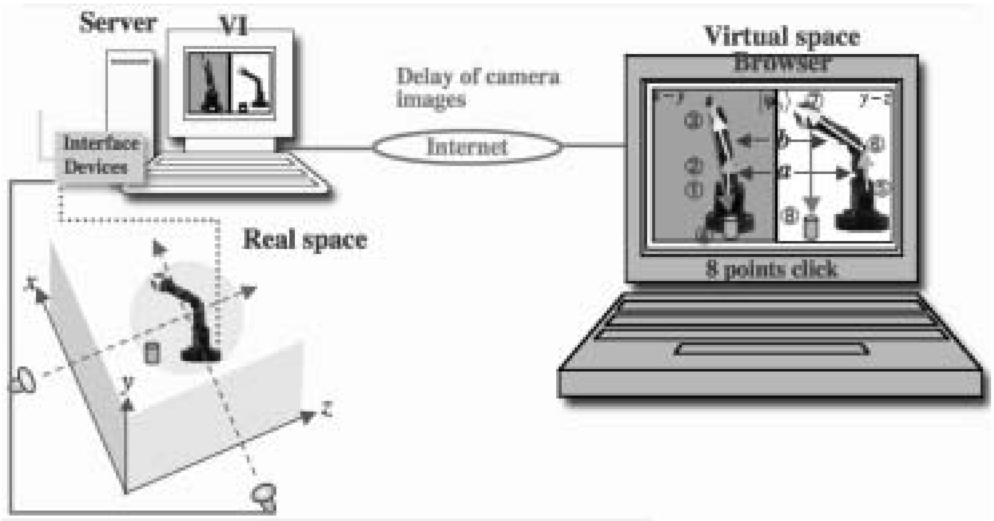


Fig. 2.4.1 System composition of “Remote control VI for a robot arm”. The robot-arm does not have any autonomous judgment ability.

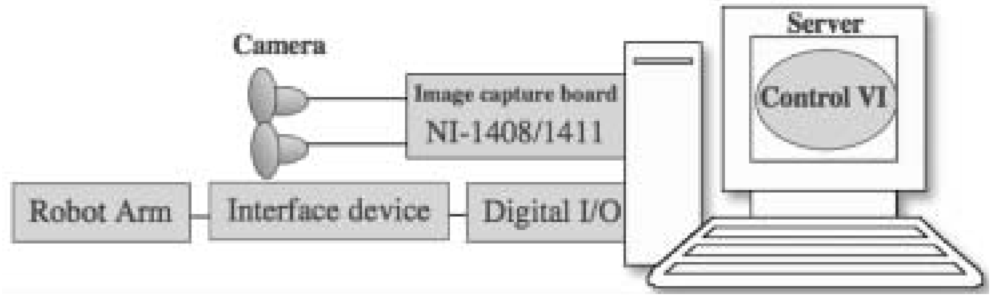


Fig. 2.4.2 Composition of the interface system.

The outline of the algorithm for visual control of the robot-arm is illustrated in Fig. 2.4.3. As the robot-arm does not have any autonomous ability, in order to operate it visually we have to know the present state (the initial state) $|\Psi_0(\boldsymbol{a}, \boldsymbol{b})\rangle$ of the robot-arm and the position of an object. The present state of the two arms and the position of the object are represented by three vectors $\boldsymbol{a}=(a_x, a_y, a_z)$, $\boldsymbol{b}=(b_x, b_y, b_z)$ and $\boldsymbol{D}=(D_x, D_y, D_z)$. The vectors $\boldsymbol{a}$, $\boldsymbol{b}$ and $\boldsymbol{D}$ are specified by clicking on eight points on two camera images on a remote browser. The images of the robot-arm are captured by two cameras set at right angles. In this way, the three dimensional information on the present state of the system is input into the control VI installed in the remote server. The control VI in the server computes a desirable state (the final state) $|\Psi_f(\boldsymbol{a}', \boldsymbol{b}')\rangle$ to get the object. This is done by numerically solving the equations,

$$|\boldsymbol{a}'| = |\boldsymbol{a}|,\ |\boldsymbol{b}'| = |\boldsymbol{b}|,\ \boldsymbol{a}' + \boldsymbol{b}' = \boldsymbol{D},\ \boldsymbol{a}' \times \boldsymbol{b}'\big|_y = 0. \tag{1}$$

Equation (1) is actually a simultaneous equation for the components of vectors $\boldsymbol{a}'=(a_x', a_y', a_z')$, $\boldsymbol{b}'=(b_x', b_y', b_z')$, which are the vectors representing the final states of the two arms of the robot-arm. The first (second) equality of eq. (1) represents the invariance of the length of the first (second) arm. The third equation represents the condition for getting the object. The last one in eq. (1) guarantees that the two arms are in the same plane, i.e., the arms do not kink at the joints.

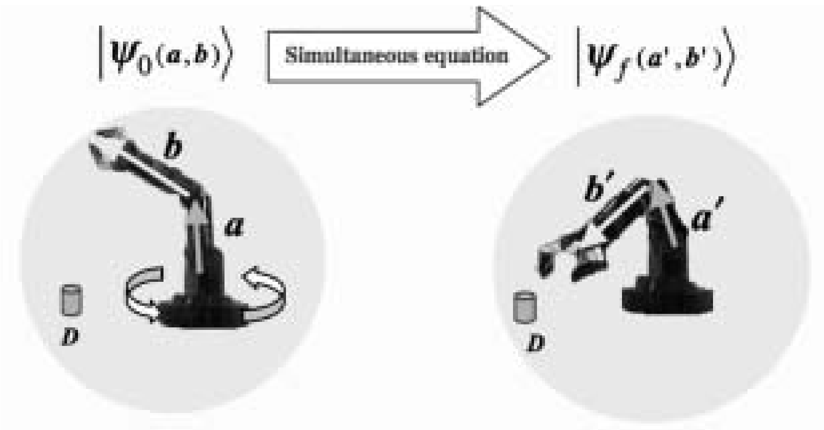


Fig. 2.4.3 Time evolution of the robot-arm. The final state $|\Psi_f(\boldsymbol{a}', \boldsymbol{b}')\rangle$ of the robot-arm is determined by solving a simultaneous equation for the components of vectors $\boldsymbol{a}'$ and $\boldsymbol{b}'$.

Once the final state $|\Psi_f(\boldsymbol{a}', \boldsymbol{b}')\rangle$ of the arms is determined, the VI computes control commands for the robot-arm to get to the final state. The commands are obtained by equations,

$$\begin{aligned}
&\theta_1 = M(a_z)I(S_{xz}(\boldsymbol{a}),\boldsymbol{i}),\ \boldsymbol{a}_1 = \boldsymbol{R}_y(\theta_1)\boldsymbol{a},\ \boldsymbol{b}_1 = \boldsymbol{R}_y(\theta_1)\boldsymbol{b},\ \boldsymbol{a}'_1 = \boldsymbol{R}_y(\theta_1)\,\boldsymbol{a}',\ \boldsymbol{b}'_1 = \boldsymbol{R}_y(\theta_1)\,\boldsymbol{b}',\\
&\theta'_1 = M(a_{1_z})I(S_{xz}(\boldsymbol{a}_1),S_{xz}(\boldsymbol{a}'_1)),\ \boldsymbol{a}_2 = \boldsymbol{R}_y(\theta'_1)\,\boldsymbol{a}_1,\ \theta_2 = M(a_{2y} - a'_{1y})I(\boldsymbol{a}_2,\boldsymbol{a}'_1),\\
&\theta_1 = M(a_z)I(S_{xz}(\boldsymbol{a}),\boldsymbol{i}),\ \boldsymbol{a}_1 = \boldsymbol{R}_y(\theta_1)\boldsymbol{a},\ \boldsymbol{b}_1 = \boldsymbol{R}_y(\theta_1)\boldsymbol{b},\ \boldsymbol{a}'_1 = \boldsymbol{R}_y(\theta_1)\,\boldsymbol{a}',\ \boldsymbol{b}'_1 = \boldsymbol{R}_y(\theta_1)\,\boldsymbol{b}',\\
&\boldsymbol{b}_2 = \boldsymbol{R}_z(\theta_2)\boldsymbol{R}_y(\theta'_1)\,\boldsymbol{b}_1,\ \theta_3 = M(b_{2y} - b'_{1y})I(\boldsymbol{b}_2,\boldsymbol{b}'_1),
\end{aligned} \tag{2}$$

where $\boldsymbol{i}$=(1, 0, 0) and $R_y(\theta)$ and $R_y(\theta)$ are respectively usual rotation matrices around the axes y and z, i.e.,

$$R_y(\theta) = \begin{pmatrix} \cos\theta & 0 & \sin\theta \\ 0 & 1 & 0 \\ -\sin\theta & 0 & \cos\theta \end{pmatrix},\ R_z(\theta) = \begin{pmatrix} \cos\theta & -\sin\theta & 0 \\ \sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{pmatrix}. \tag{3}$$

In eq. (2) we defined the function $\cos^{-1}(\boldsymbol{p}\cdot\boldsymbol{q}/|\boldsymbol{p}||\boldsymbol{q}|)$, $M(x) \equiv x/|x|$ and $S_{xz}(p) \equiv \sqrt{p_x{}^2 + p_z{}^2}$.

Once $\boldsymbol{a}$ and $\boldsymbol{b}$ have been specified by clicking eight points on camera images on a remote browser, the control VI installed in the remote server performs these processes automatically.

The rotation of the tip-arm is operated by clicking with Shift key on any two points on the left camera image on a remote browser. The rotation angle is determined by the difference in *x*-coordinates of the two clicked points. On the other hand, the grasp operation is done with control button attached to the front panel of the VI. In Fig. 2.4.4 we show the front panel of the VI. Figure 2.4.5 shows a scene of a test of the remote control. As the block diagram of the VI is very complicated we give it to Appendix E. In the front panel we designed the virtual LEDs, which are turned on when the clicking is done successfully. By using this control system we can operate the robot-arm remotely through the Internet with no mis-operation that should be caused by the delay of image-communications between two remote sites. We have also developed a remote control VI of the control button system. In Appendix F we show only the front panel of the VI. When we use this VI, however, we are prone to mis-operations due to the time difference in the camera images between two remote sites. When we use this VI, we have to operate by taking account of the delay of image-communication.

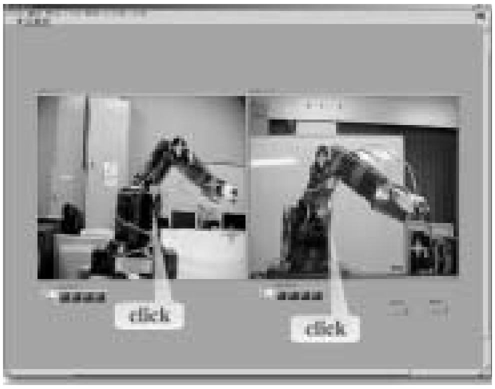


Fig. 2.4.4 The front panel of "Remote control VI for a robot arm". The block diagram of the VI is given in Appendix F.

Fig. 2.4.5 A scene of a test of the remote operation. The screens of the r.h.s. and the l.h.s. show the front panels of the VI installed on the server and a remote browser, respectively. The robot-arm interfaced to the server can be controlled from a remote browser by clicking on eight points on camera images mounted on the browser.

3. Remote control by a cellular phone

In the preceding section, we introduced some of the remote control VIs that we have developed, in particular, VIs of a mouse-click system. In this section we discuss a way of remotely controlling with a cellular phone. Figure 3.1 shows the outline of the access to the server from a cellular phone. Our aim is to operate all VIs by a cellular phone. For this purpose, we adopted a method of remote login to the Windows server from a cellular phone. In this way we can operate, from a cellular phone, any VIs on the Windows server. In order to operate VIs on a remote browser we need to install “LabVIEW Run Time Engine” to the remote client where the browser runs. This is easily done for a Windows client because the “LabVIEW Run Time Engine” can be downloaded free. However, no cellular phone version of such “LabVIEW Run Time Engine” is available as yet. This is one of the reasons why we took the method of remote login to the Windows server from a cellular phone. For the remote control by a cellular phone the control VIs of mouse-click system that we have explained in the preceding section is particularly useful in view of the fact that it is very inconvenient to quickly operate control buttons on the small window of a cellular phone.

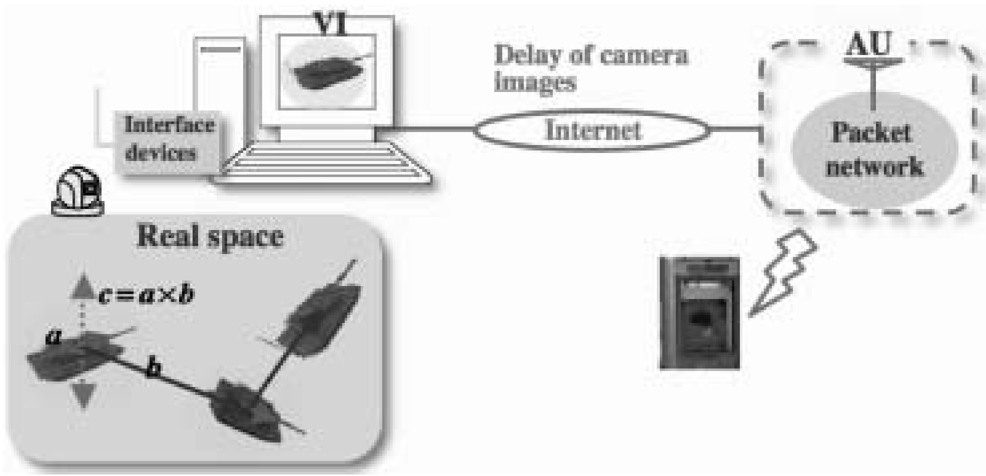


Fig. 3.1 System composition of the remote operation of VIs by a cellular phone.

The remote login to the Windows server from a cellular phone was realized by an application software VNC. The VNC for Windows server is available free. On the other hand, the VNC for a cellular phone, which is called μVNC, is not available free. We purchased it from Hitachi Systems Ltd. In our present system, the cellular phone is limited to AU.

Figure 3-2 shows scenes of tests of the remote control of the RC tank and robot arm by a cellular phone. In these tests the control VIs of mouse-click system are used.

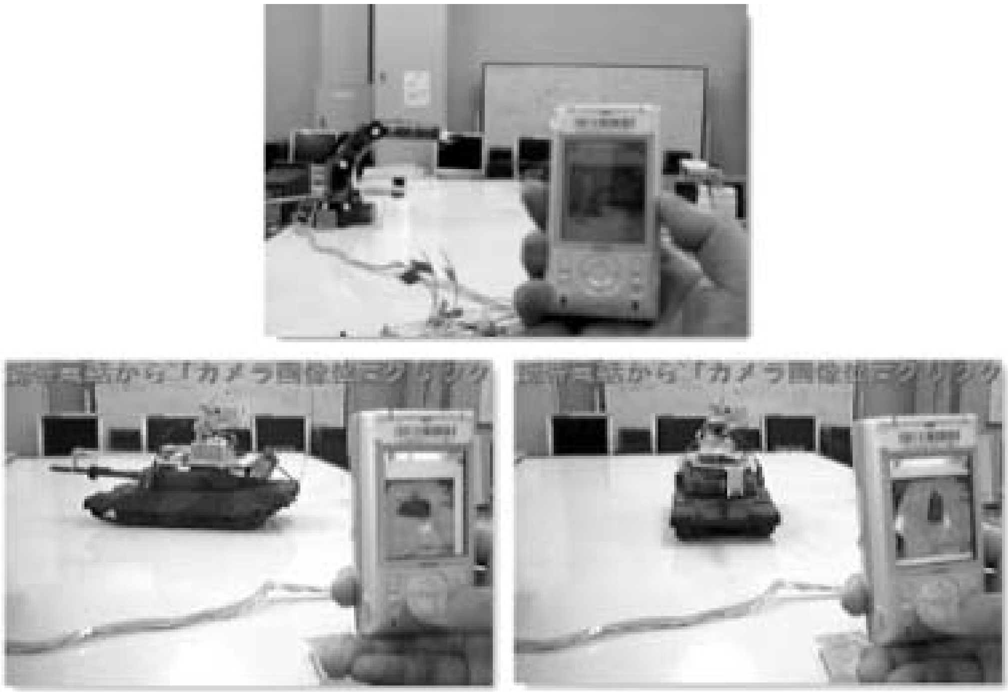


Fig. 3.2 Scenes of tests of the remote control of the RC tank and robot-arm by a cellular phone.

4. A compact system developed by using "Compact Vision System"

In the developed systems that we have explained so far Windows servers are used for VIs. It seems that this system is of too large in its scale. For practical use it is important to make it a more compact system. We show that it is possible to make the system compact by using "Compact Vision System (CVS)" [2]. The CVS works with a real time OS called "LabVIEW Real Time". Therefore, programs of event-drive type do not run on the CVS, namely the VIs of mouse-click system that we have developed for Windows servers do not work on the CVS as they are. On the other hand, the VIs of control button system work on the CVS only by replacing some of LabVIEW modules with their real time versions. In order to run the VIs of mouse-click system on the CVS we need to modify the structure of the VIs that we have developed for Windows servers. Figure 4.1 shows the concept of the modification of the structure of the VIs of mouse-click system. As seen in the figure, for the CVS we have to separate a user interface part out of the VIs. Further we have to renounce the browser for the user-interface tool. Then, we devised to use an EXE file of LabVIEW program for the user interface part. Such an EXE file runs on any Windows clients with "LabVIEW Run Time Engine", which can be downloaded from a web site free. Therefore, we can use the EXE file of LabVIEW program for the user interface part of the VI. In this modified system, the control commands are generated by the LabVIEW EXE file on a Windows client when we click on the camera images on an image window given by the EXE file. The control commands are sent to the CVS through the Internet in TCP/IP. Then the VIs on the CVS control the drive systems interfaced to the CVS. In this way we developed a compact version of the remote control system of mouse-click system. We show the composition of the system in Fig. 4.2. Figure 4.3 is a scene of a test of the remote control using the CVS. We omit showing the LabVIEW program.

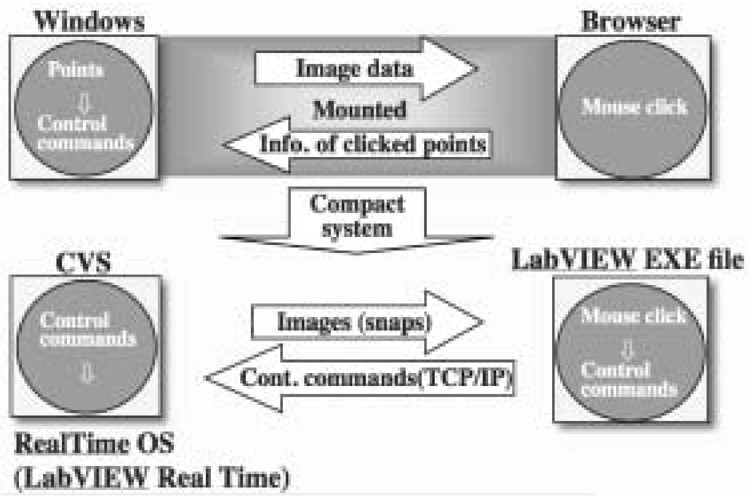


Fig. 4.1 Concept of compactification of the remote control VIs of mouse-click system.

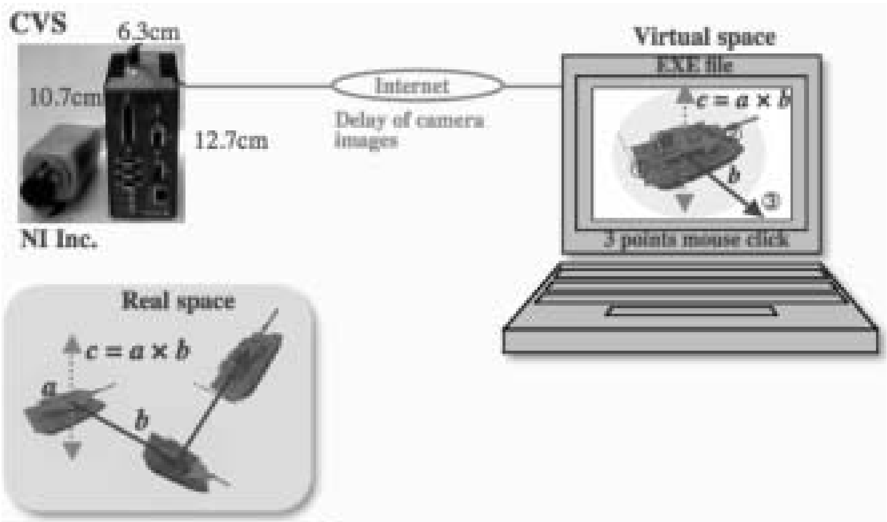


Fig. 4.2 System composition of a compact version of the remote control VIs for a RC tank (mouse-click system). Compact Vision System is a product of National Instruments Ltd.

5. Security system and access to control VIs from outside

In this kind of remote control system using the Internet, the network security is very important. We set a security server for our developed system. The security server distributes tasks requested from remote clients to each control server where the VI for the requested task is running. In this way, for remote clients all VIs look as if they are running not on the control servers but on the security server. This makes the security server to be exposed to attacks from outside. However, the VIs on the control servers can be safe even if the security server is attacked from outside. We opened four internet ports on the security server. Three of them are assigned to the access from a remote browser or LabVIEW EXE file. The rest one is assigned to the access from a cellular phone. In order to access each VI on the control servers from outside we first have to know the port number opened to the server where the VI is running. This can be a barrier against attackers from outside. This situation is illustrated in Fig. 5.1. When we access a VI of which name is, for example, "abc" on a control server, we just input http://www.ssss.kyoto-su.ac.jp:xxxx/abc.htm on a remote browser, where "ssss" is the node-name of the security server, "xxxx" is the port number assigned to the control server and "abc" is the VI name on the control server.

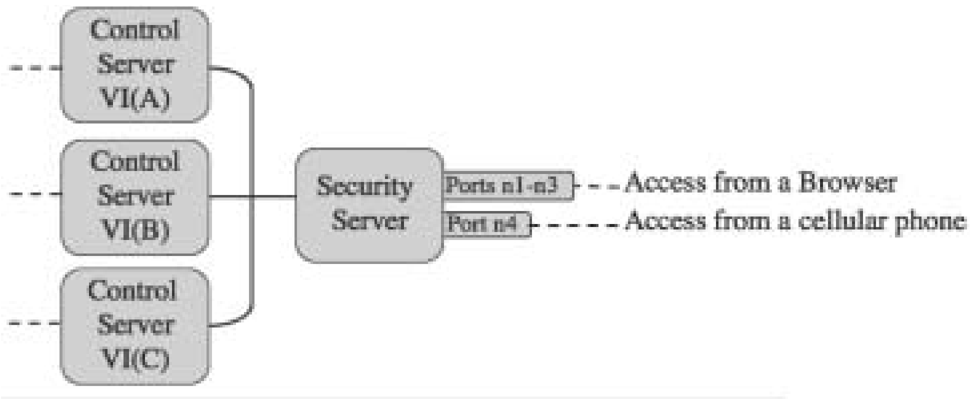


Fig. 5.1 Access to the control VIs from a remote client and a cellular phone.

We developed our systems on the assumption that LabVIEW is not installed in any remote clients. If LabVIEW is installed also in remote clients we can operate the VIs remotely by "LabVIEW Remote Panel" from the clients. In this case, we can register only allowed remote clients directly to the VIs in the control servers. By this procedure, the access to the VIs is allowed only for registered clients. Our aim is, however, to control remote drive systems by using an internet browser that can be available anywhere.

6. Summary

We have introduced remote surveillance and control systems that utilize VI technology, the Internet and a cellular phone, in particular VIs for a remote control system of mouse-clicking on camera images on a remote browser. In this kind of remote control system using the Internet, mis-controls caused by image-communication between two remote sites are severe problem. We showed how the VIs of mouse-click system are useful in eliminating such mis-controls in remote control of drive-systems. We also discussed the possibility of compactification of the system. We proposed to use CVS instead of Windows server and LabVIEW EXE file instead of an internet browser.

Our main purpose of this work was to develop remote control systems for robots that have no autonomous judgment ability. We showed that the control system of mouse-clicking on camera images works very well for such unintelligent robots.

References

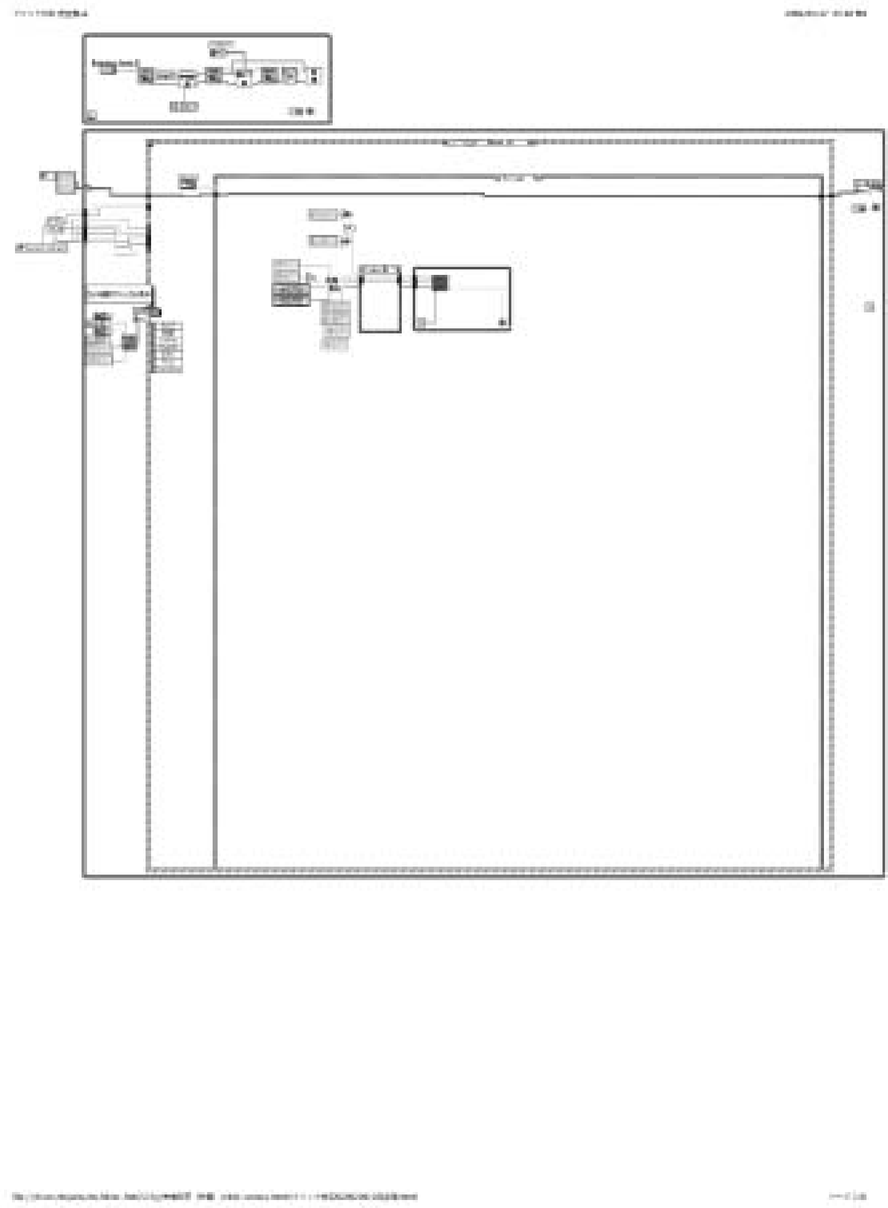
[1] R. H. Bishop, *Leaning with LabVIEW Express*, Pearson Education, Inc., publishing as Prentice Hall, 2004; 日本語訳： ロバート・H・ビショップ(日本ナショナルインスツルメンツK.K. 監訳、尾花健一郎 訳)、LabVIEWプログラミングガイド、ASCII出版、2004.

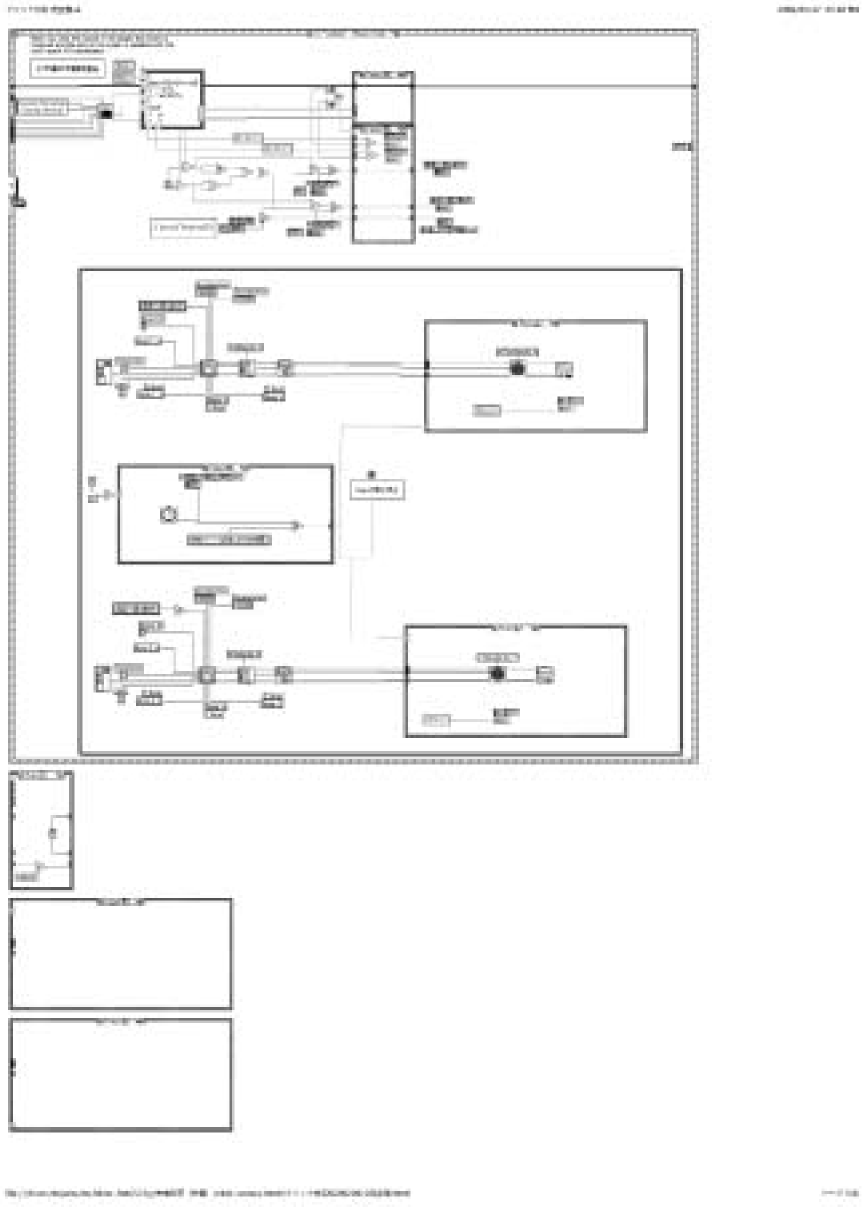
[2] Compact Vision System 1455, Products of National Instruments Inc., "*The Measurement and Automation Catalog 2005-2006*", p. 104, p. 396 .

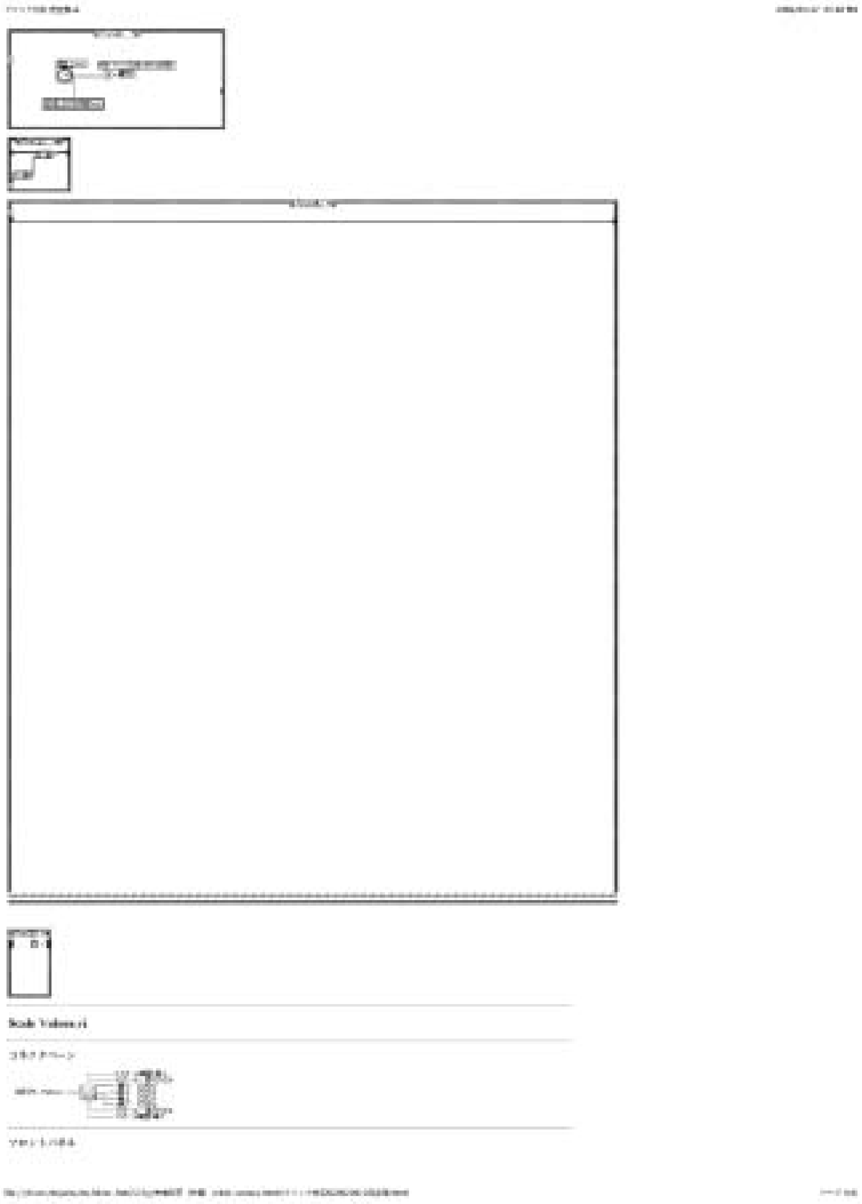
[3] Products of National Instruments Inc., "*The Measurement and Automation Catalog 2005-2006*", p. 391.

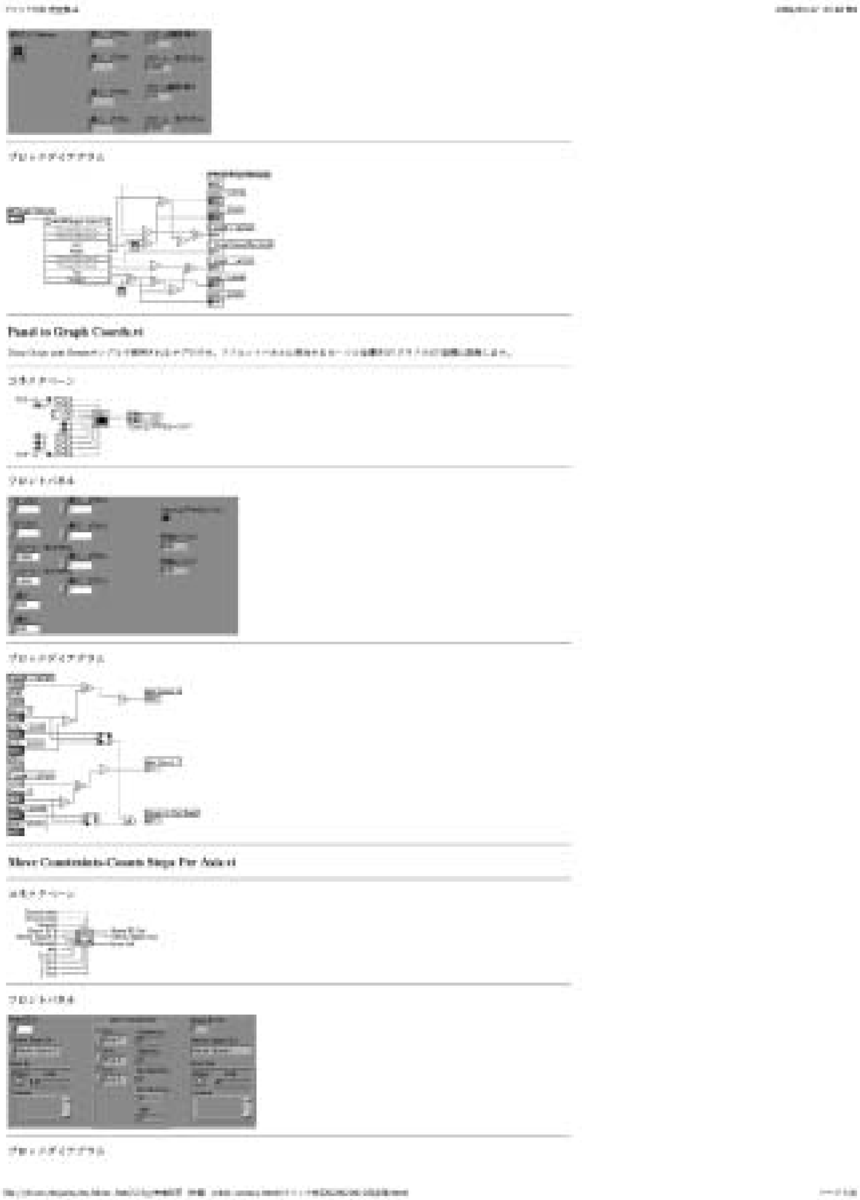
[4] Products of National Instruments Inc., "*The Measurement and Automation Catalog 2005-2006*", p. 407.

Appendix A The block diagrams of "Remote surveillance camera VI (*mouse-click control system*)".






Scale Values.vi
コネクタペーン
フロントパネル


ブロックダイアグラム

Panel to Graph Coord.vi

コネクタペーン

フロントパネル

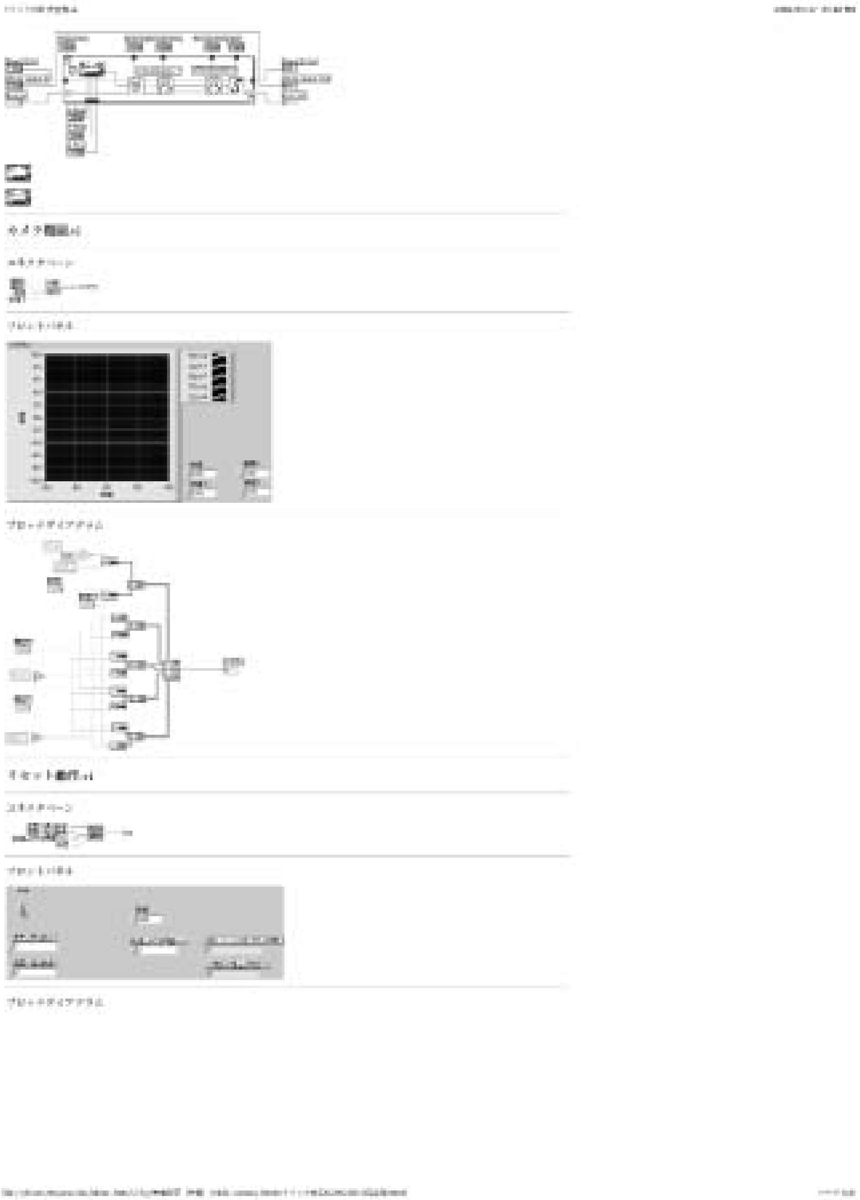
ブロックダイアグラム

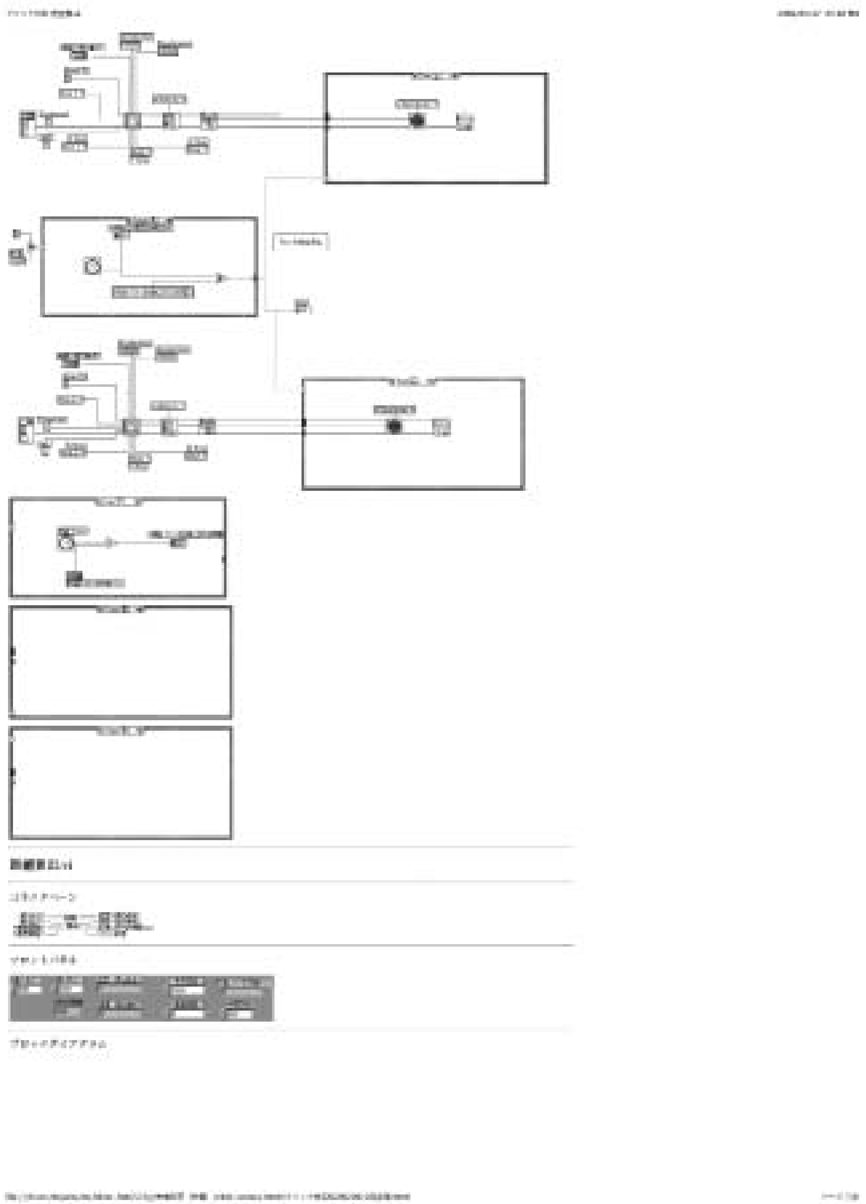
Move Continuous-Counts Steps Per Axis.vi

コネクタペーン

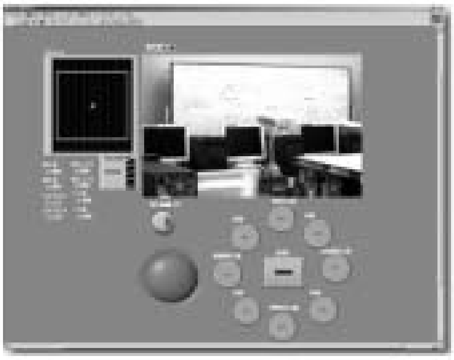
フロントパネル

ブロックダイアグラム

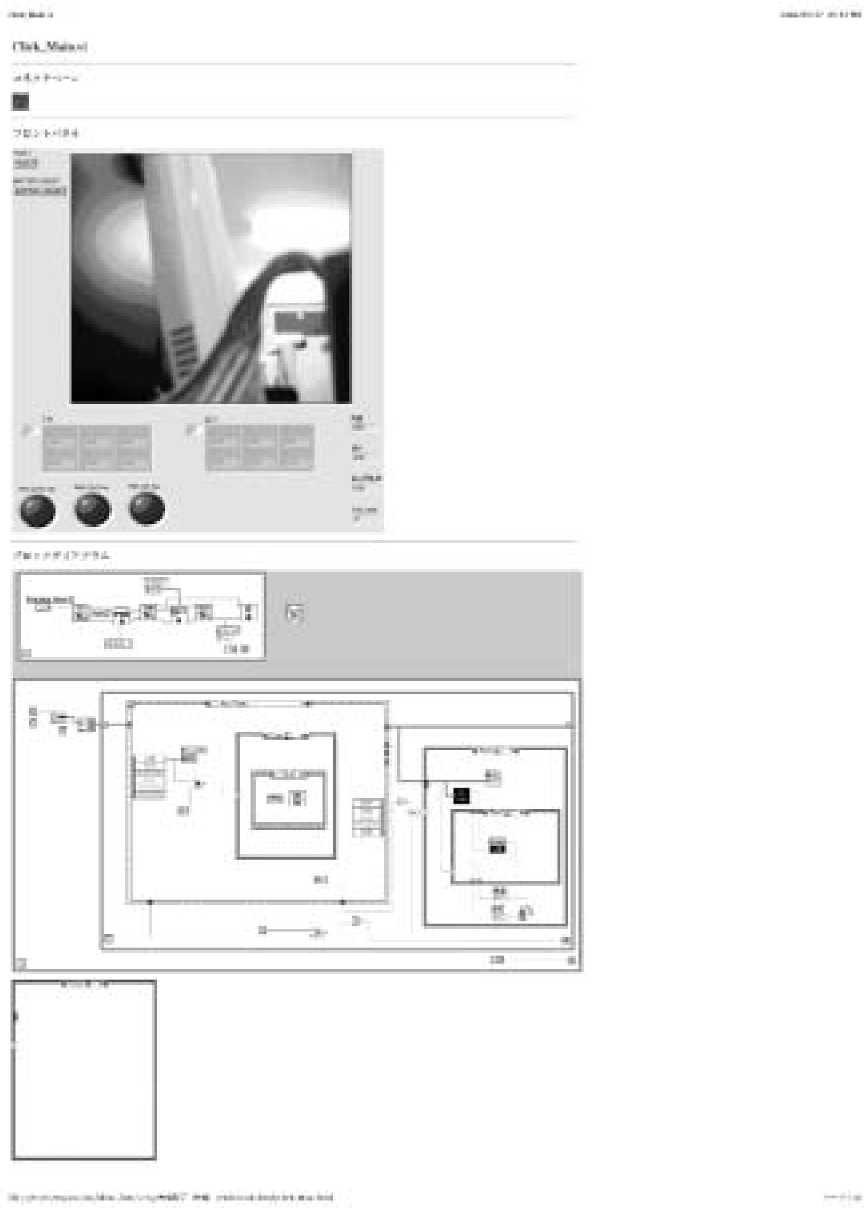


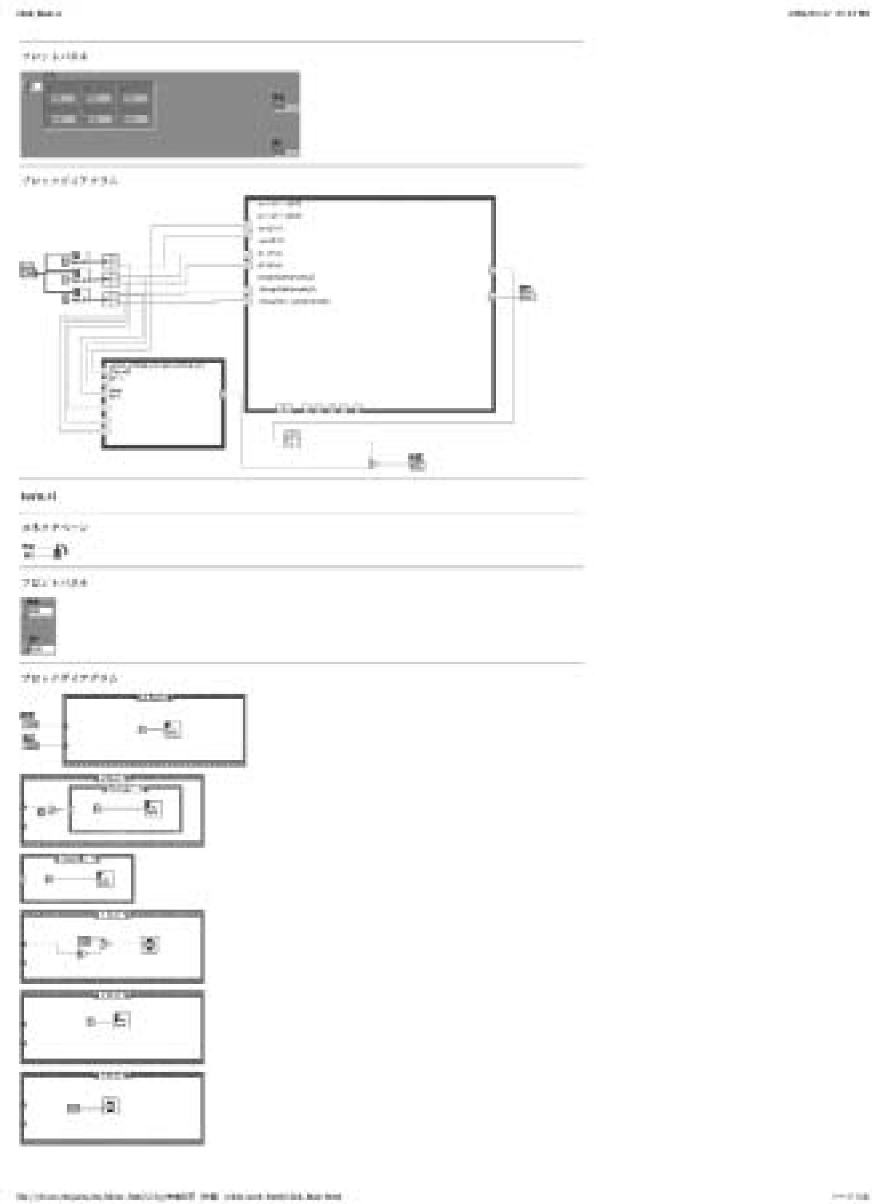


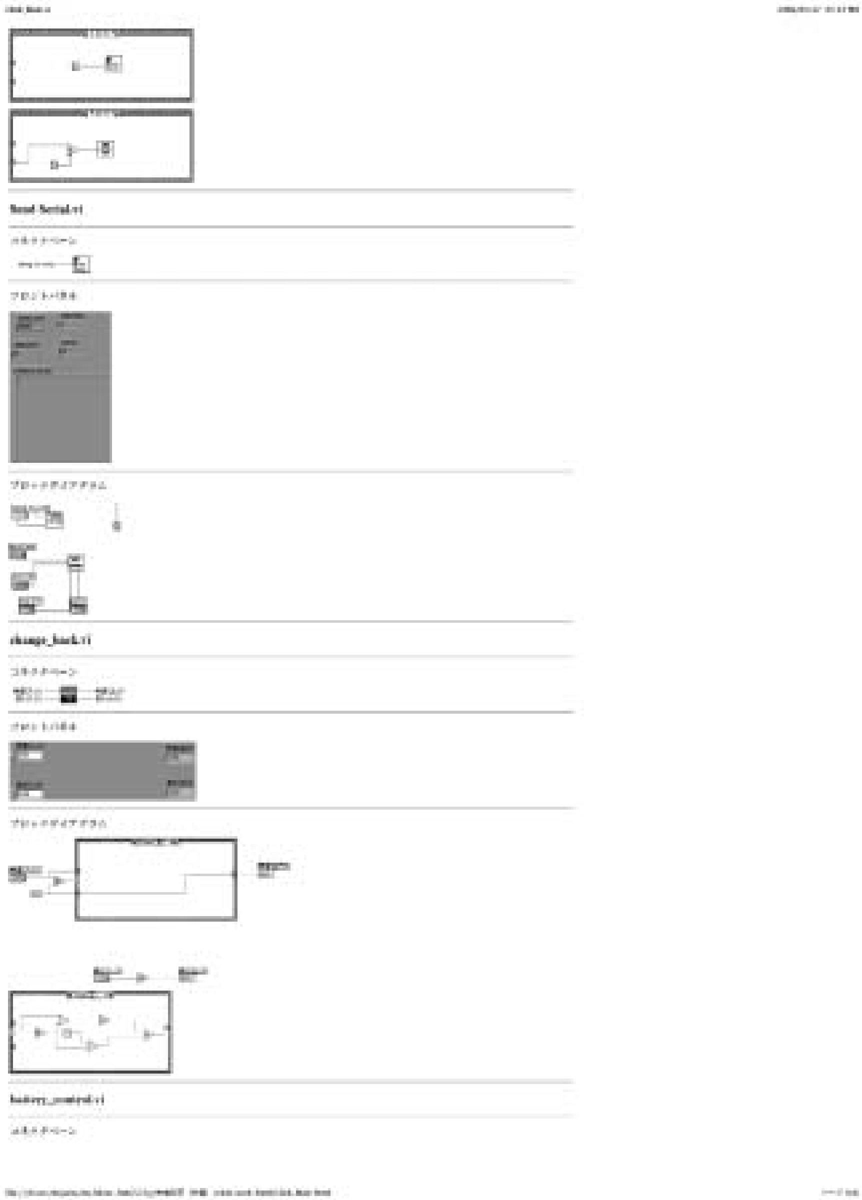
Appendix B The front panel of "Remote surveillance camera VI (*control button system*)". The surveillance camera interfaced to the server is remotely operated with the control buttons attached to the front panel of the VI that is mounted on a remote browser. We have to take account of the delay of image-communication when we use this VI. We omit to show the block diagram.

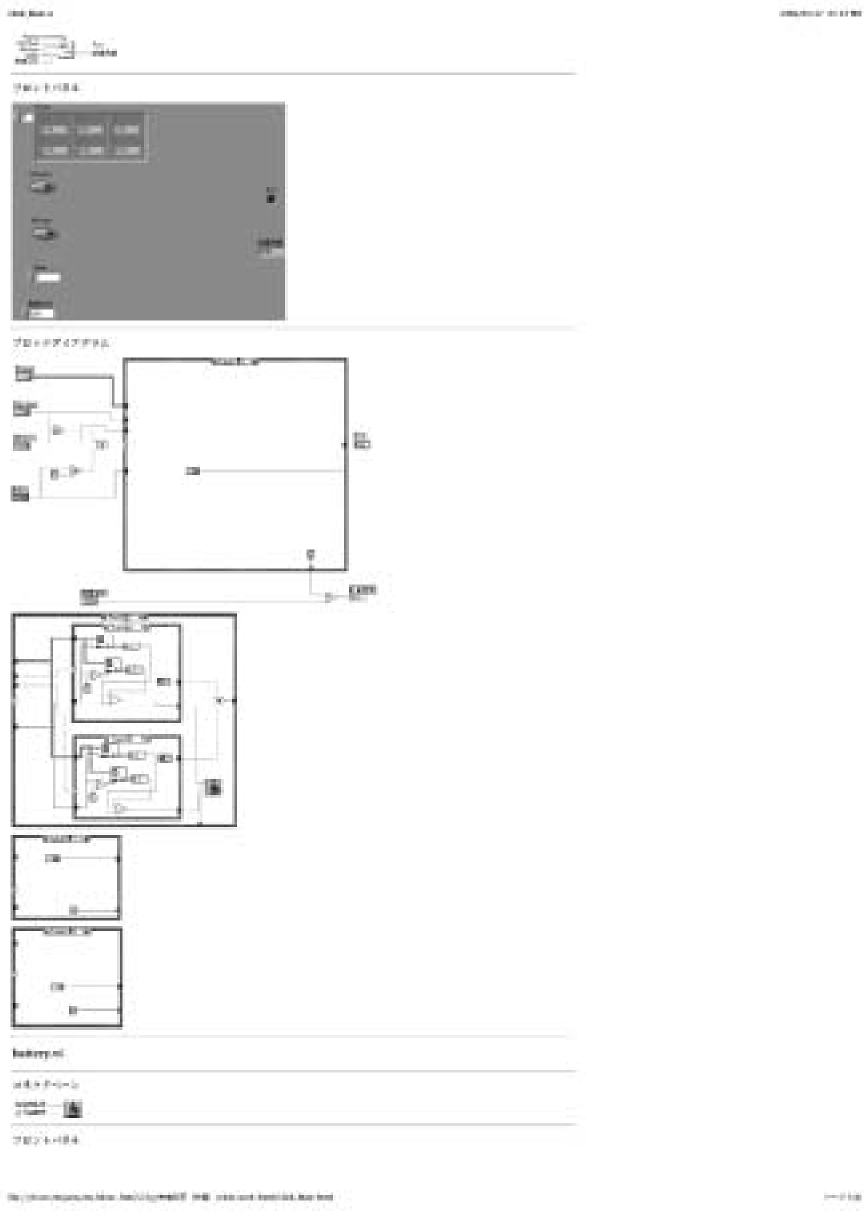


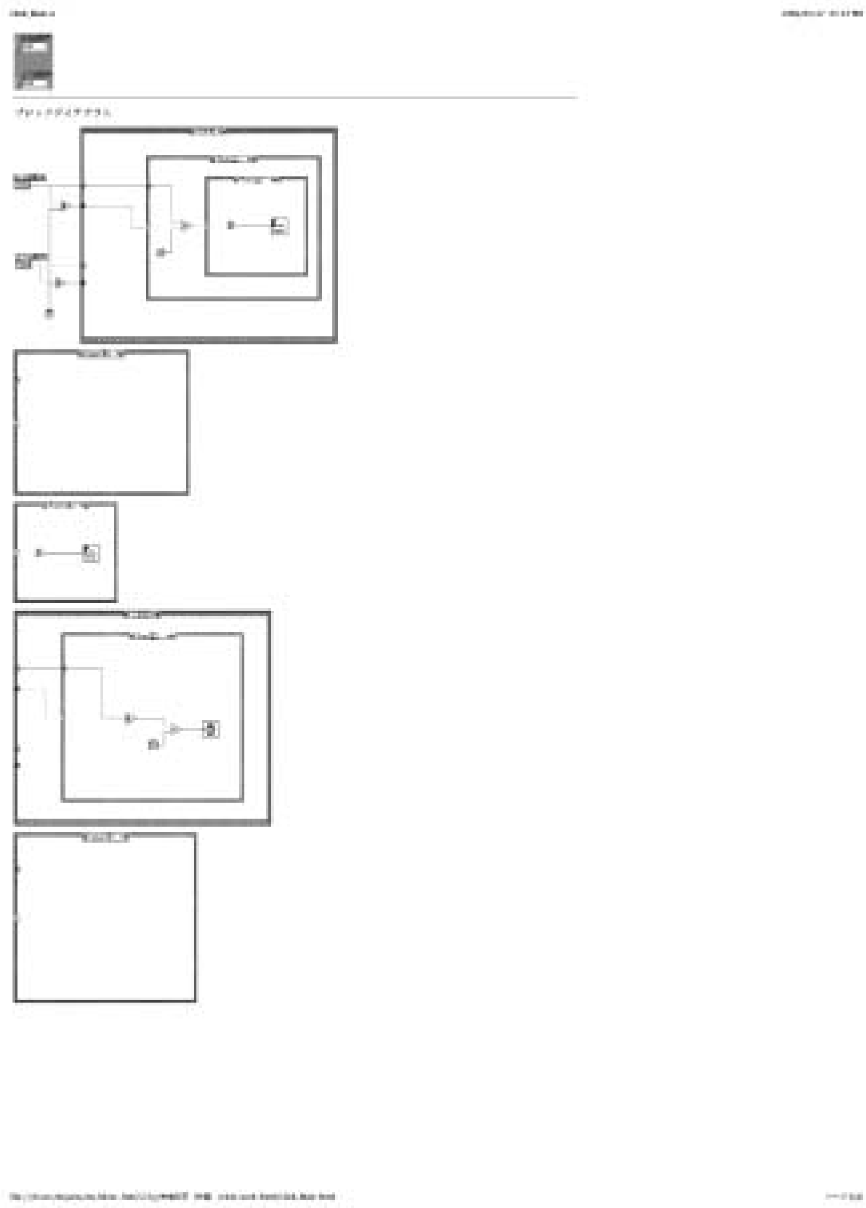
Appendix C The block diagram of "Remote navigation VI for a mobile robot (*camera-image mouse-click system; lab. fixed camera*)"

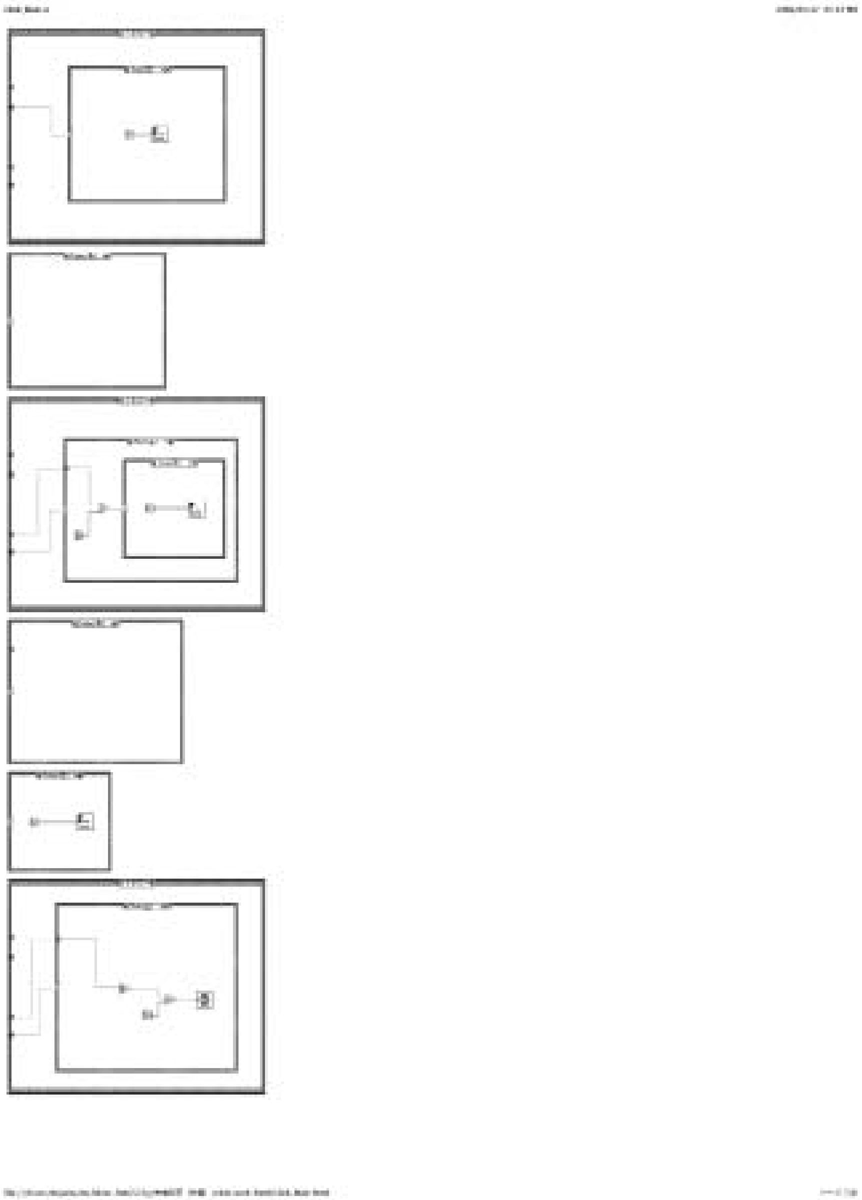


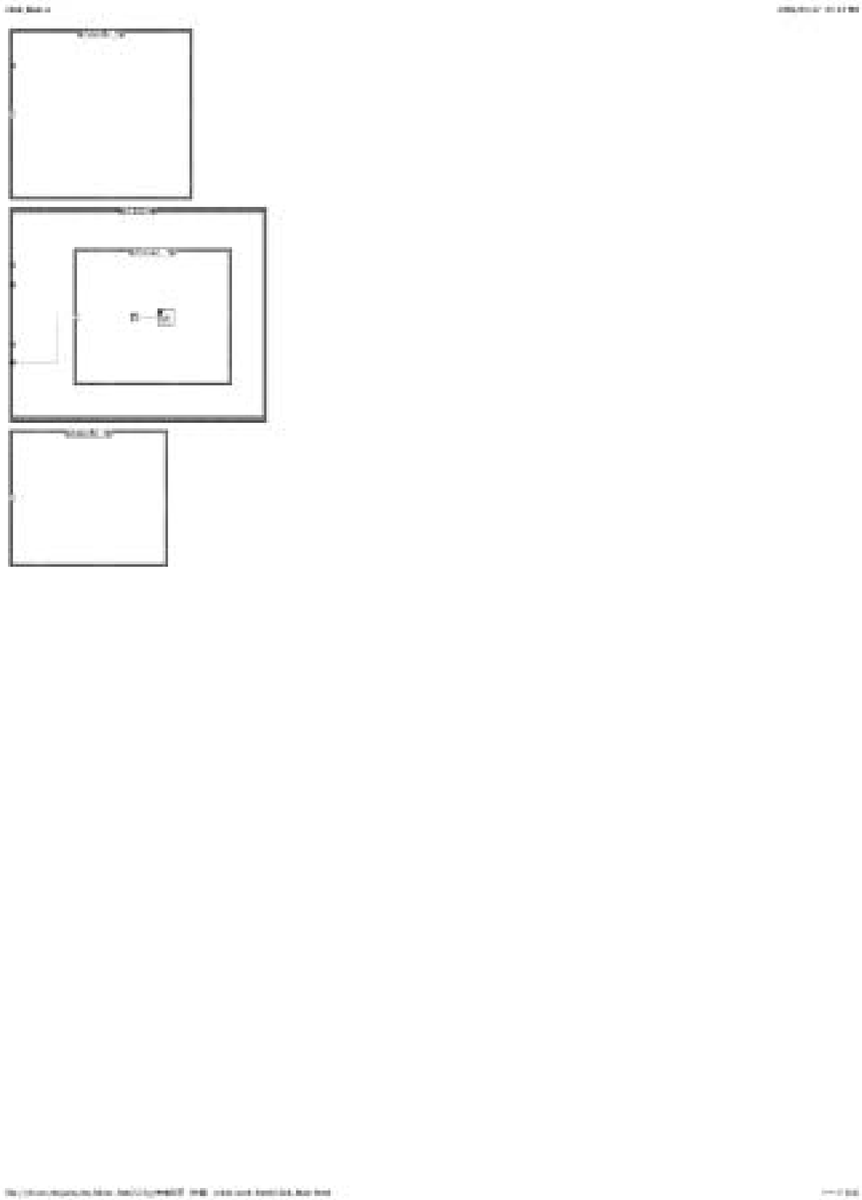



Send Serial.vi
コネクタペーン
フロントパネル
ブロックダイアグラム
change_back.vi
コネクタペーン
フロントパネル
ブロックダイアグラム
battery_control.vi
コネクタペーン



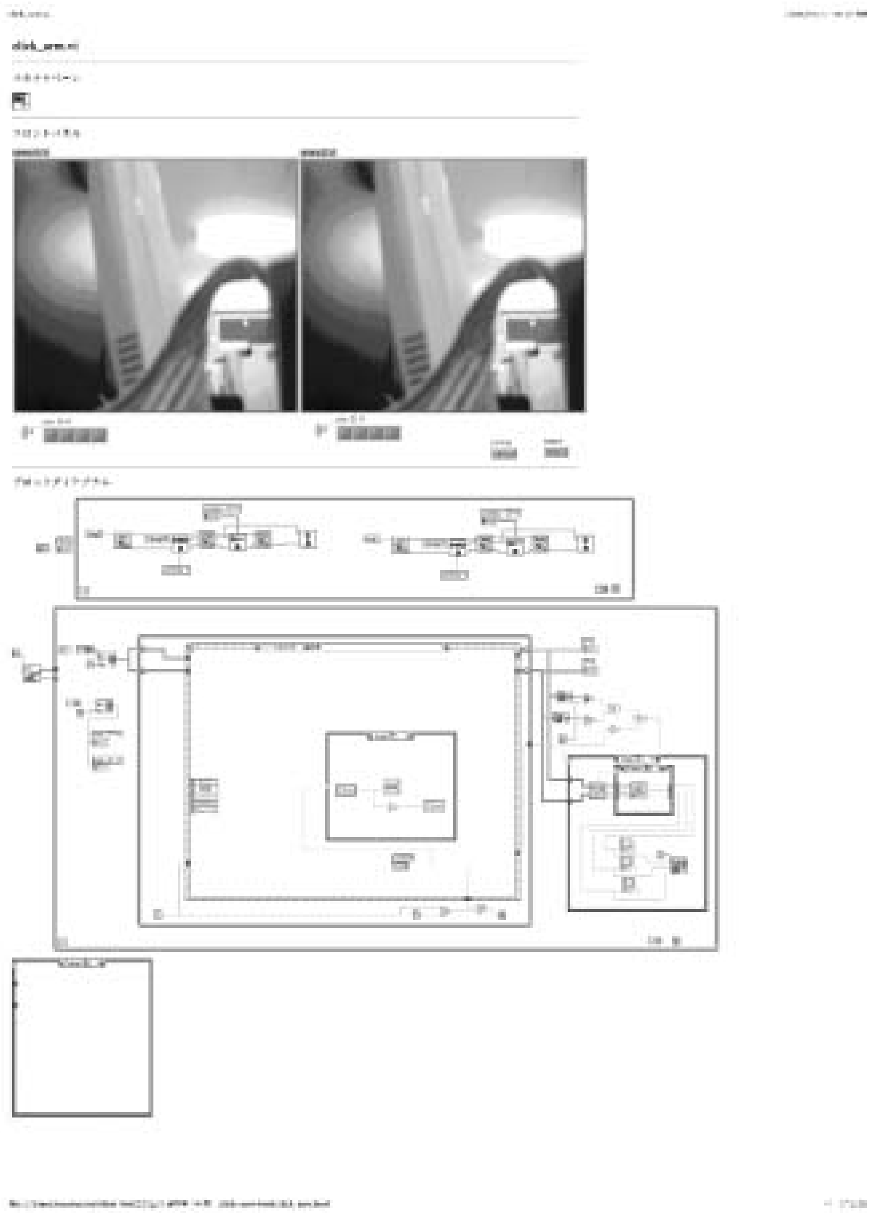


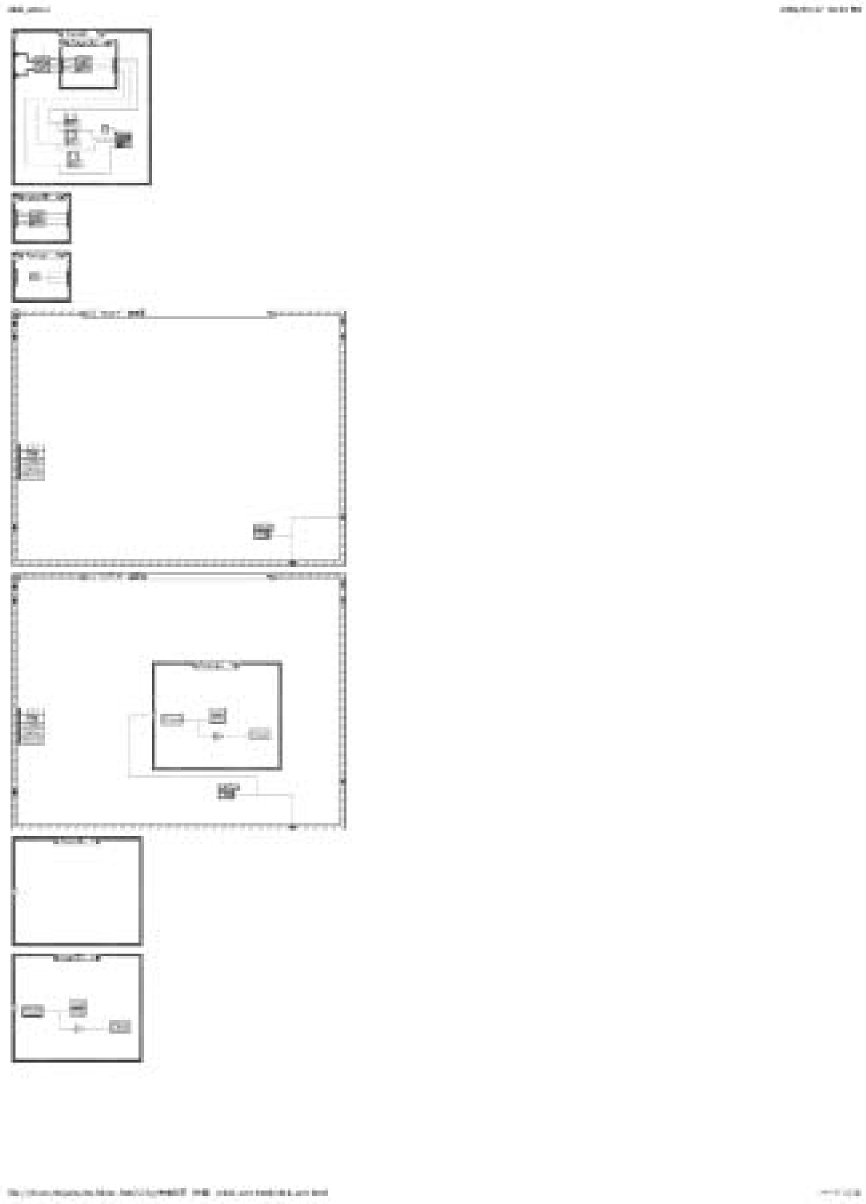


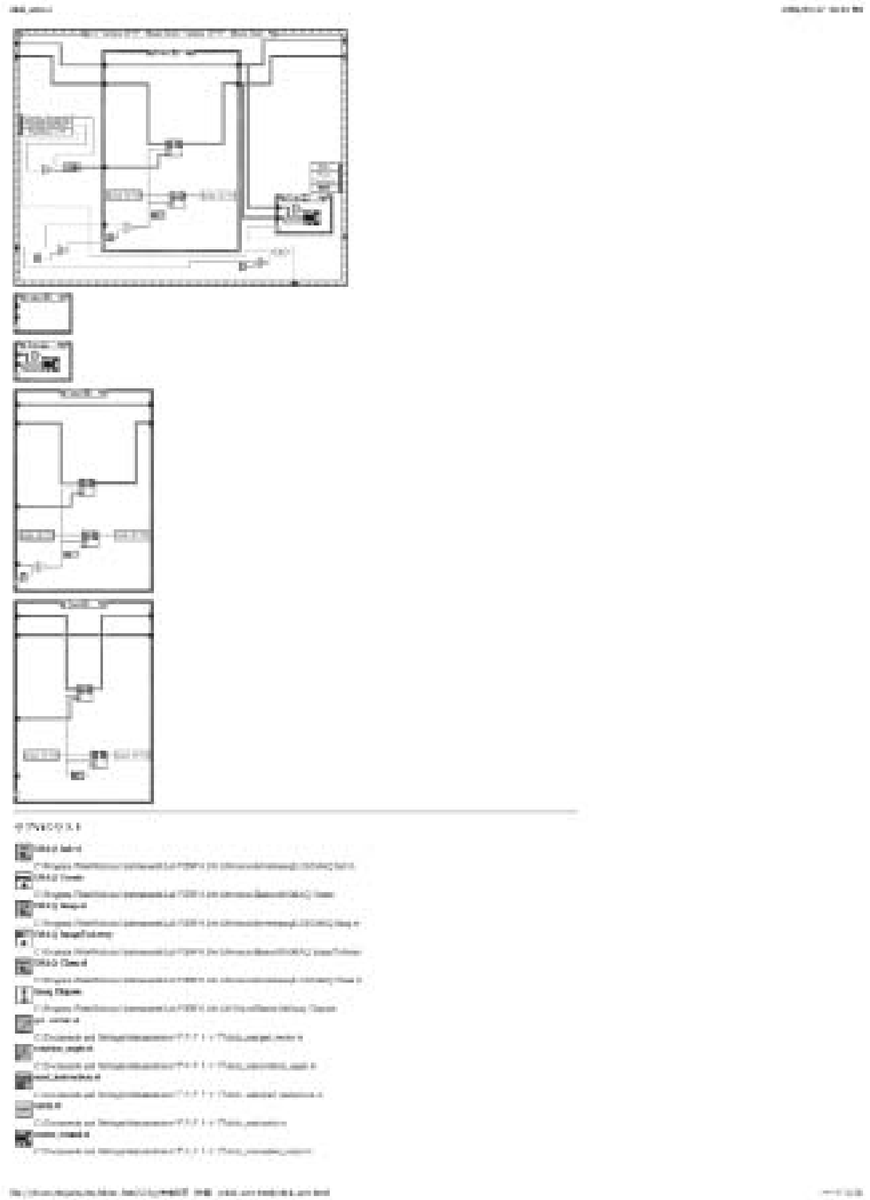


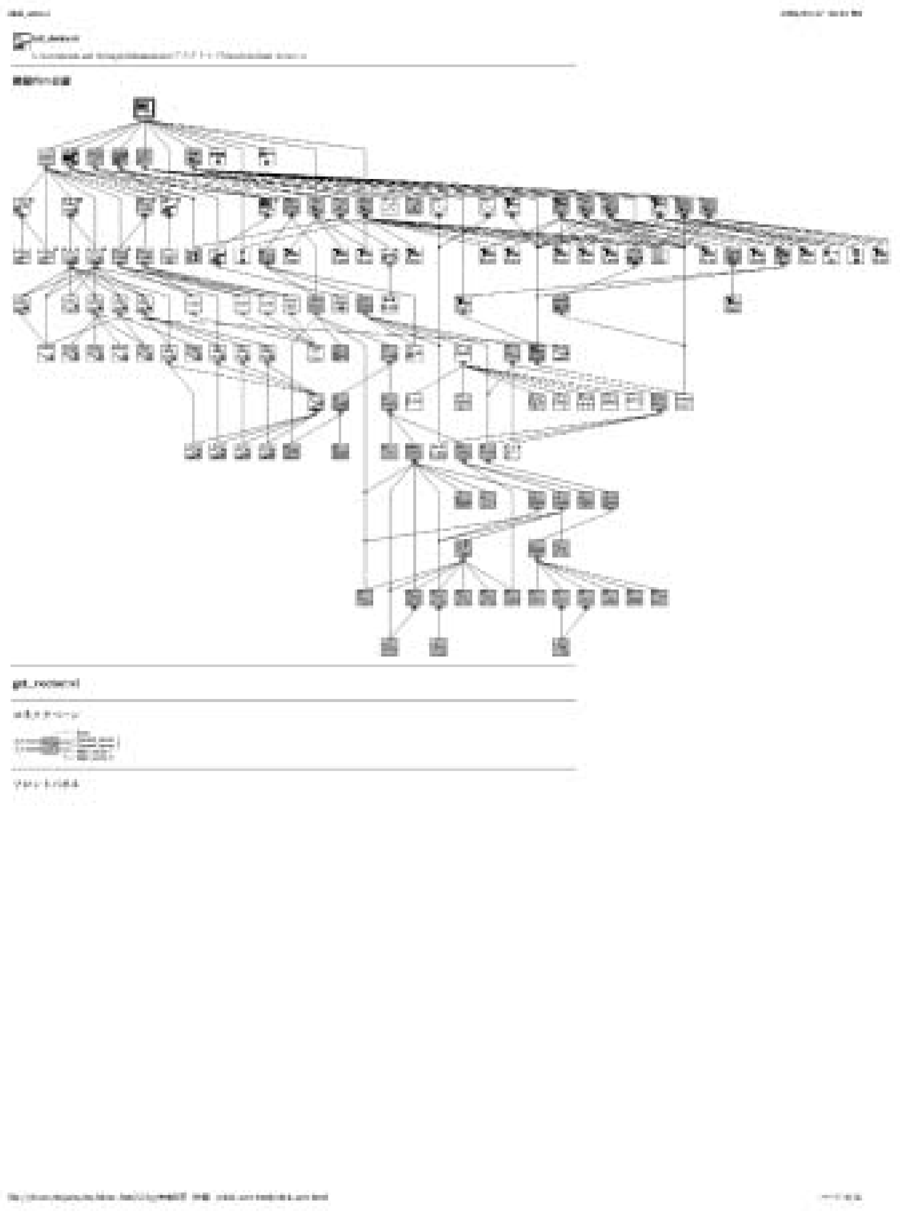
Appendix D The front panel of "Remote navigation VI for a mobile robot (*control button system*)". The RC tank interfaced to the server is controlled with the control buttons attached to the front panel of the VI that is mounted on a remote browser. We have to take account of the delay of image-communication when we use this VI. We omit to show the block diagram.

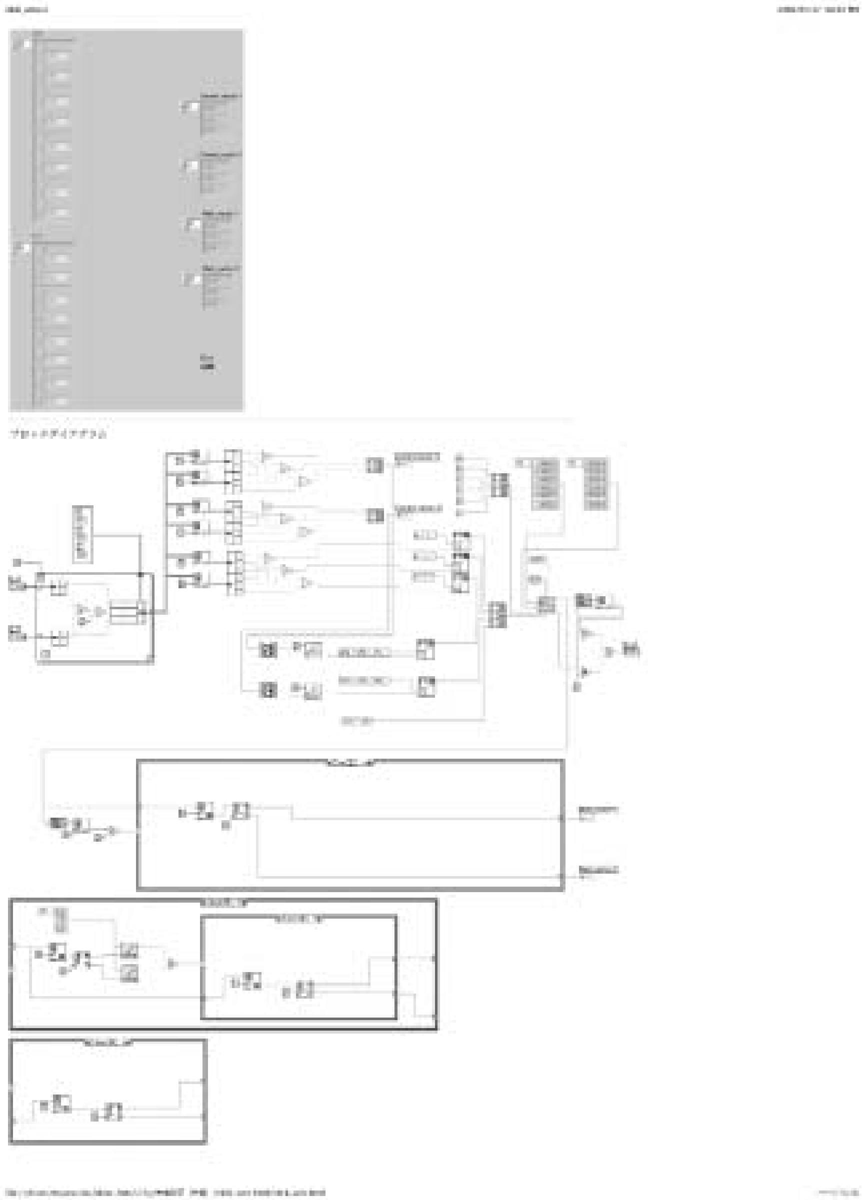
Appendix E The block diagram of "Remote control VI for a robot-arm (*mouse-click system*)".

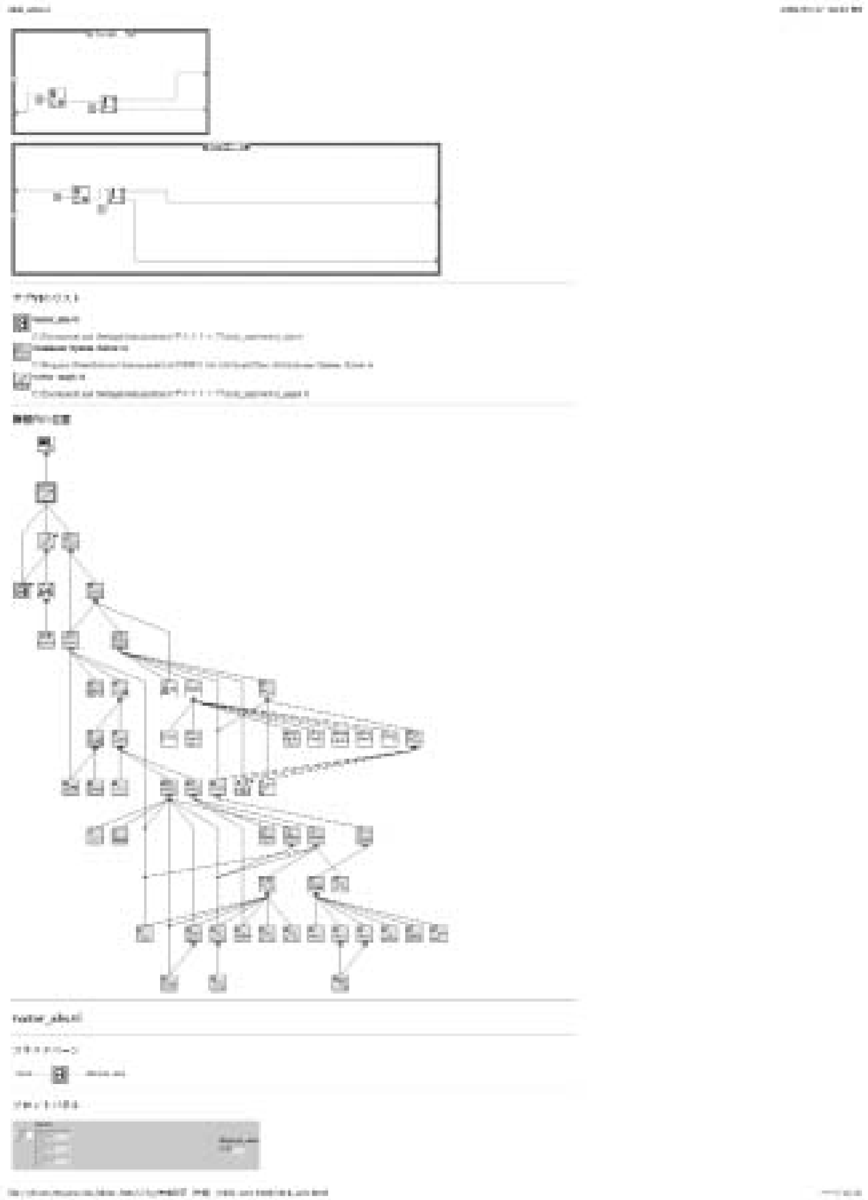


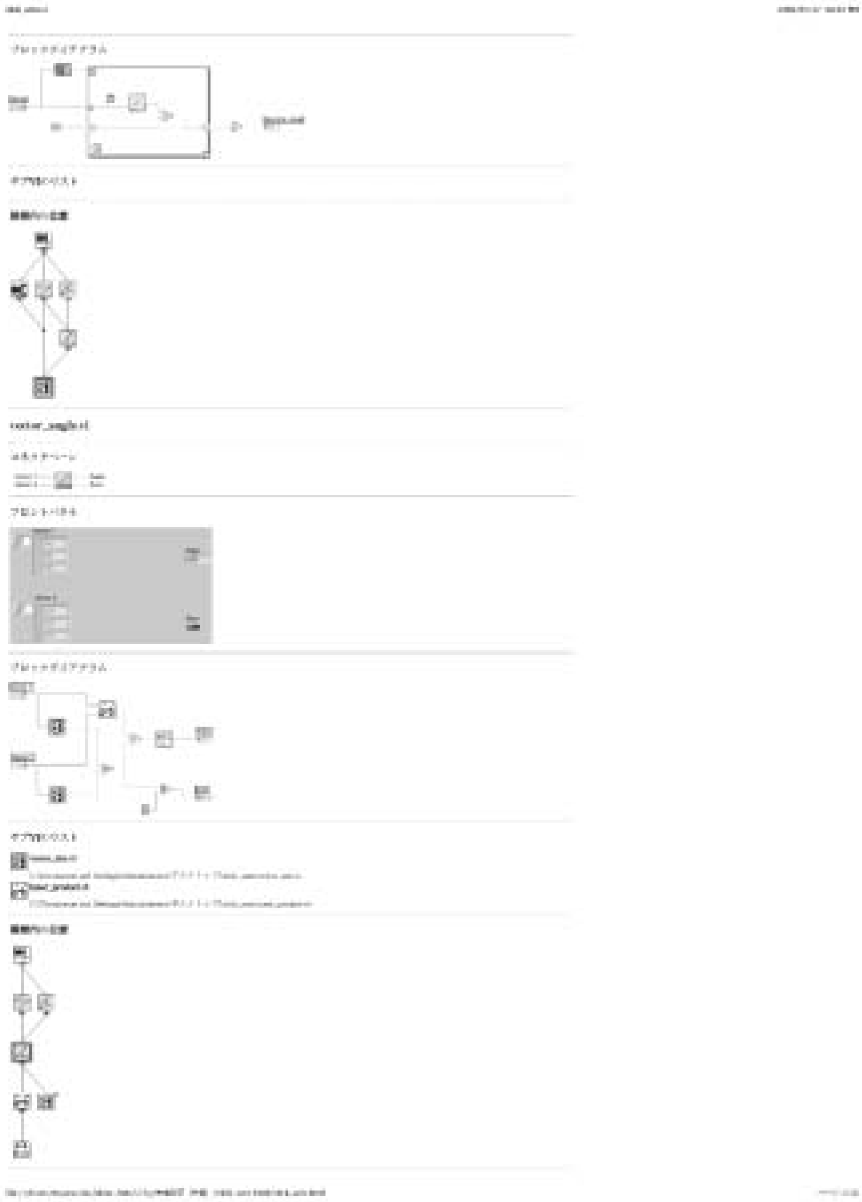


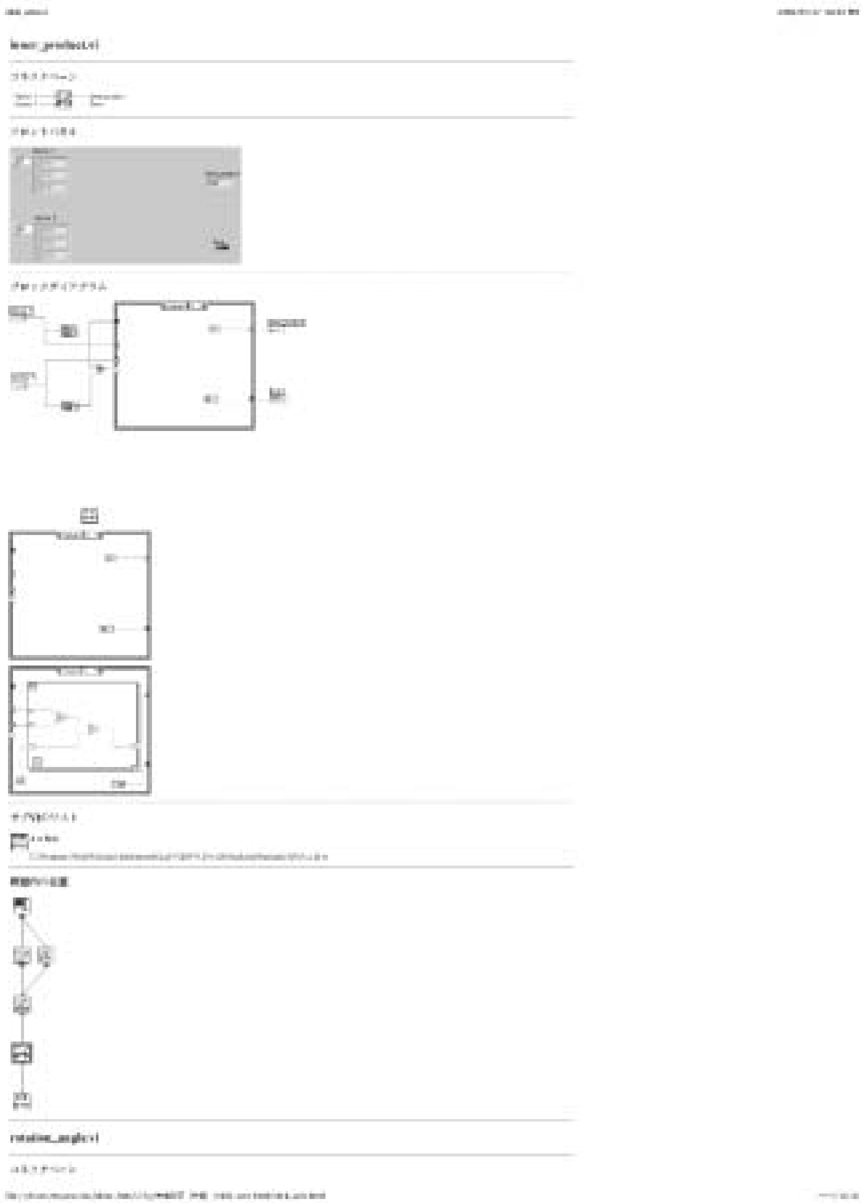


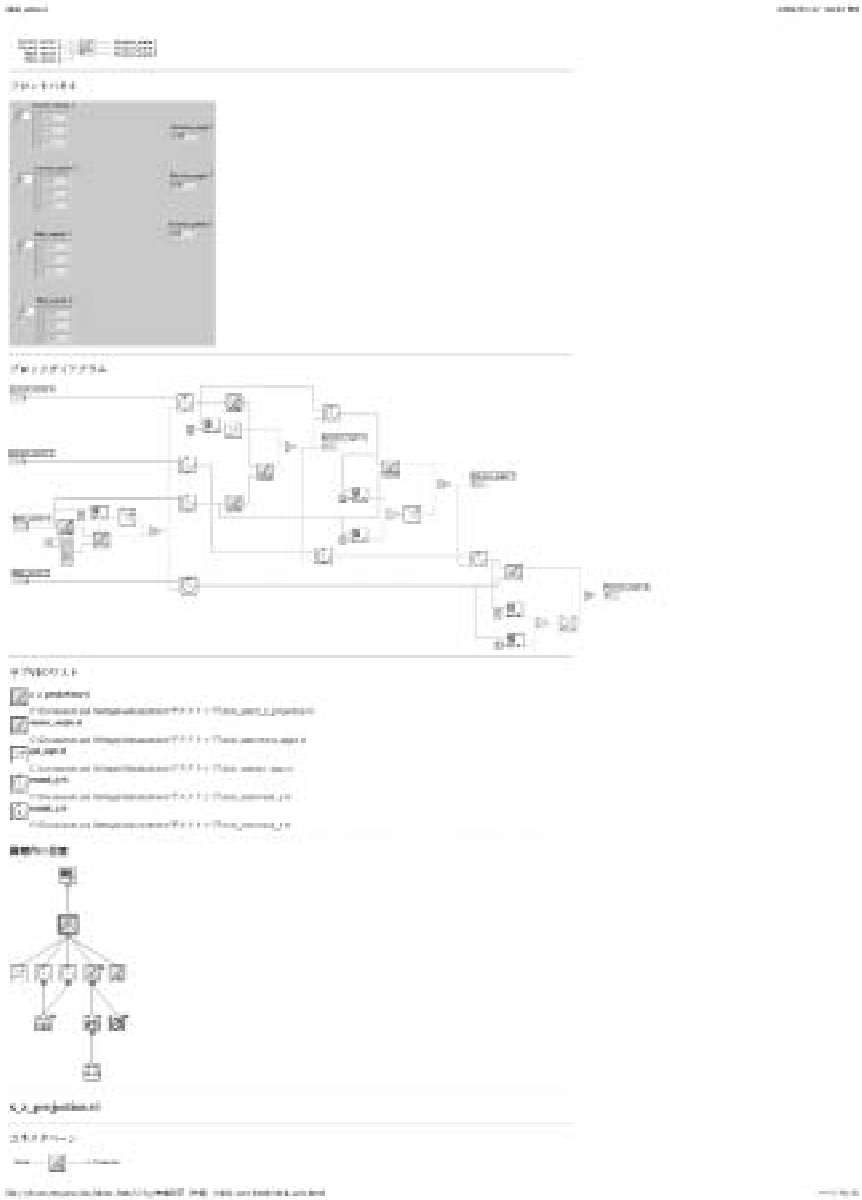


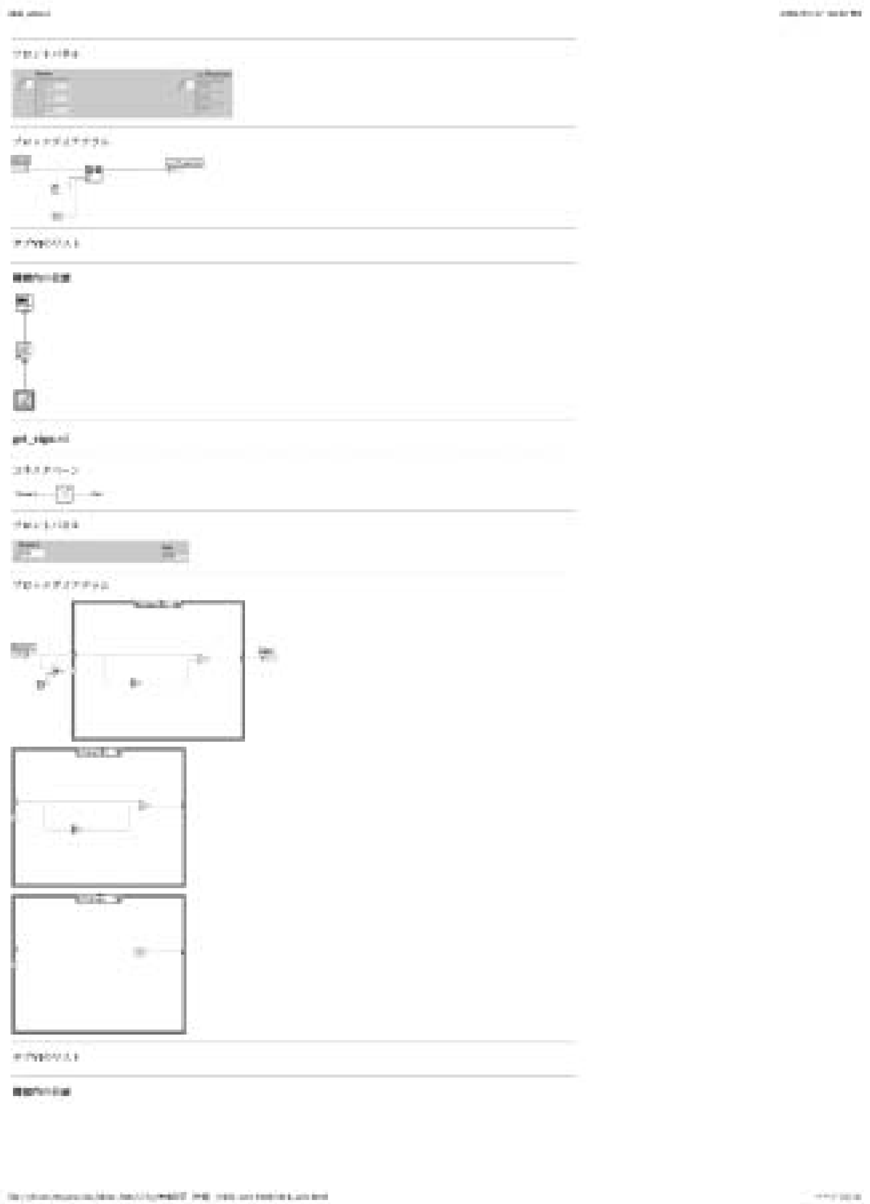


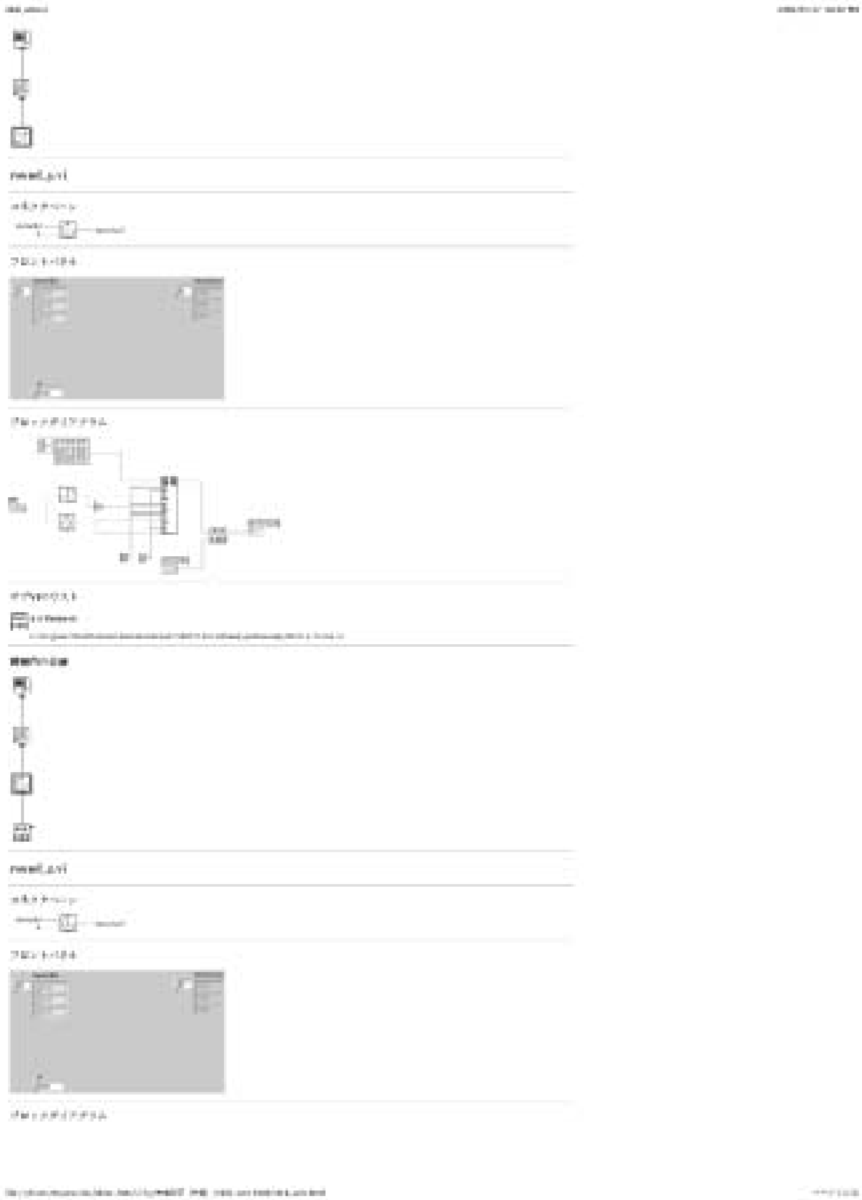


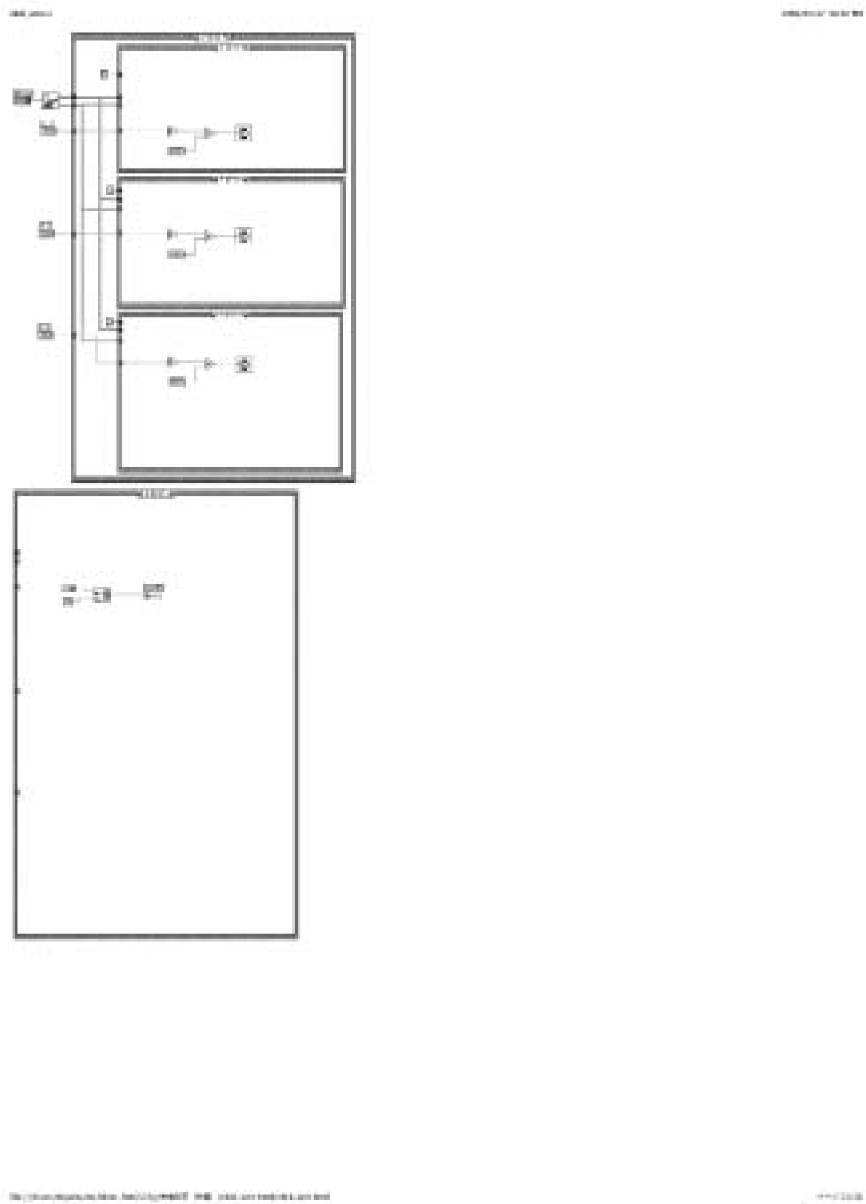


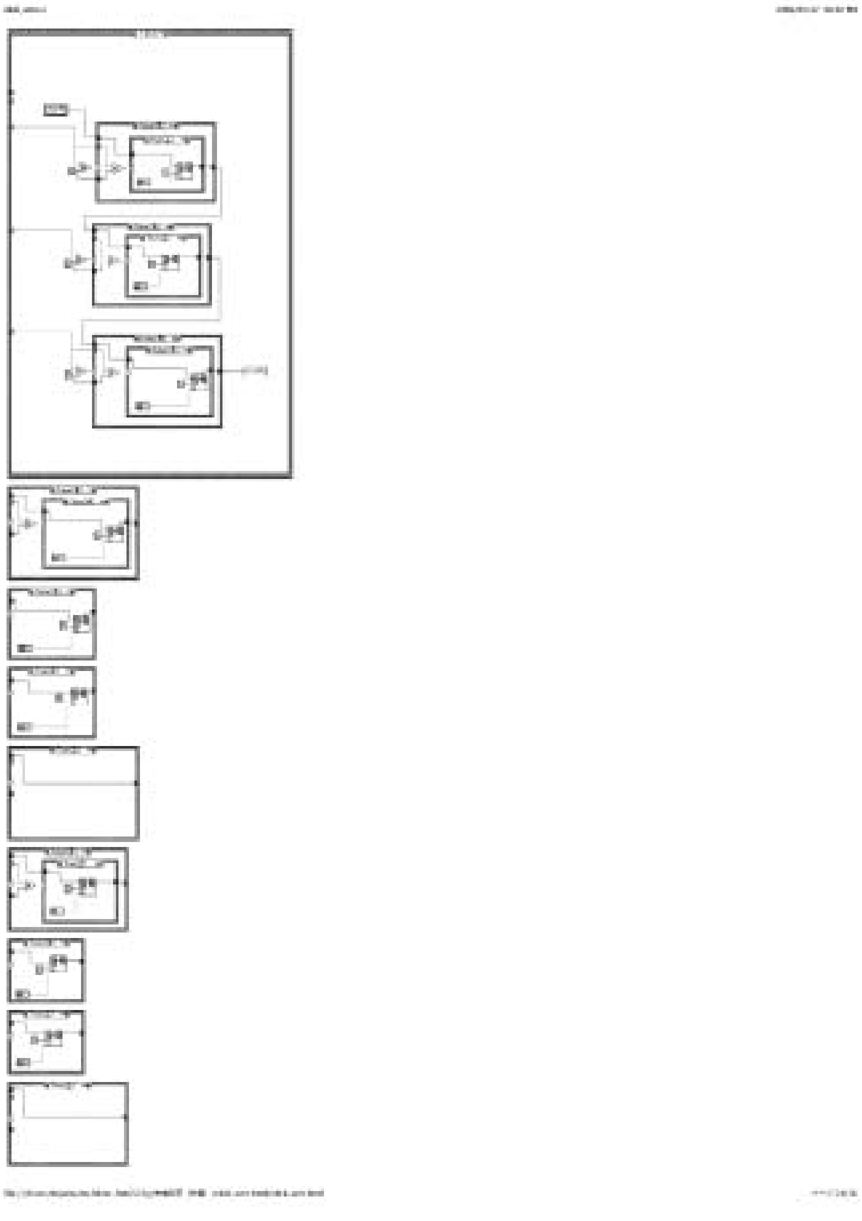


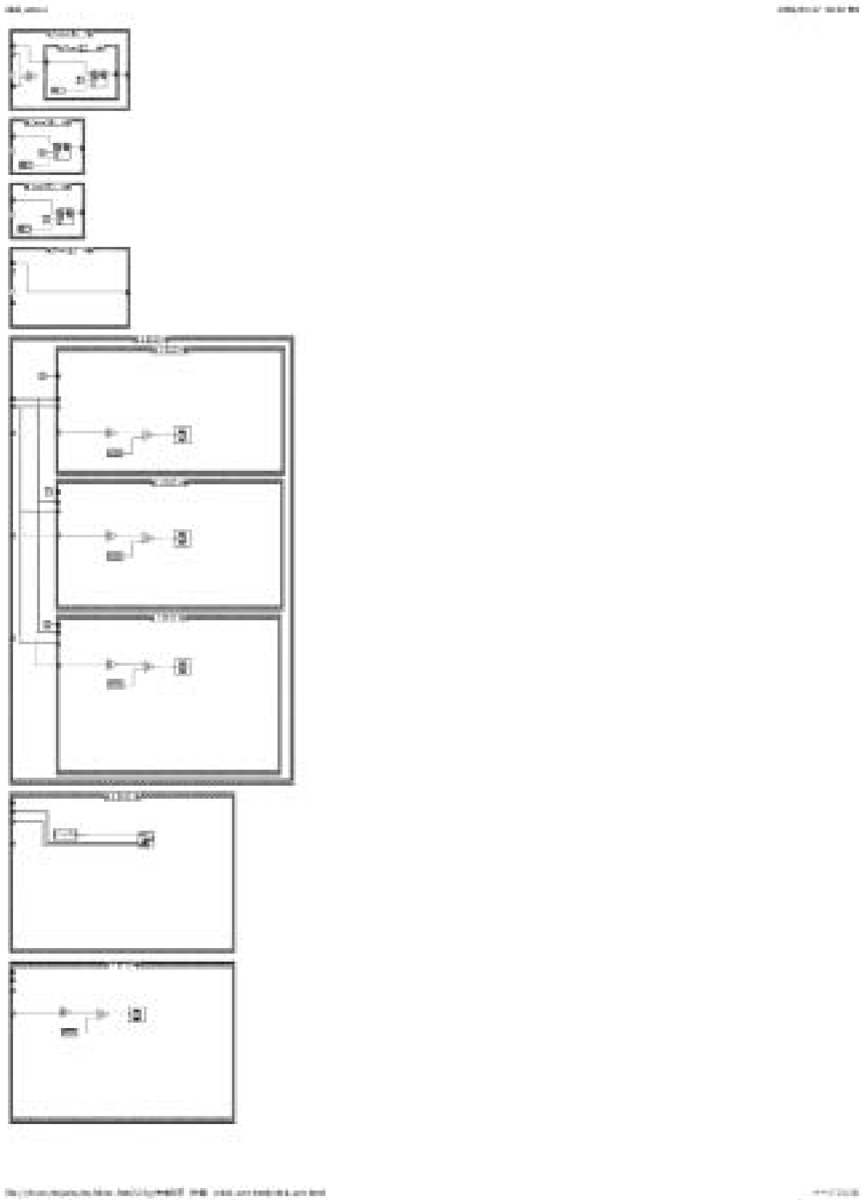


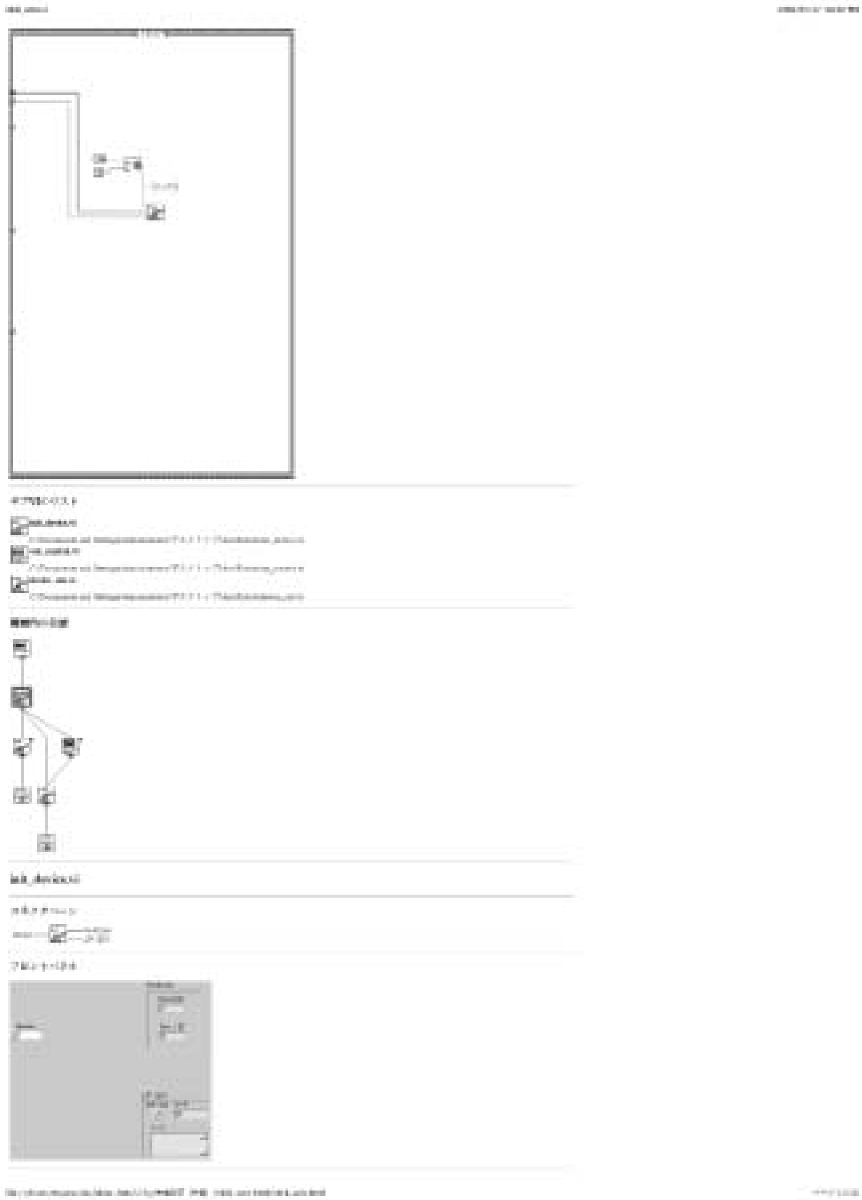


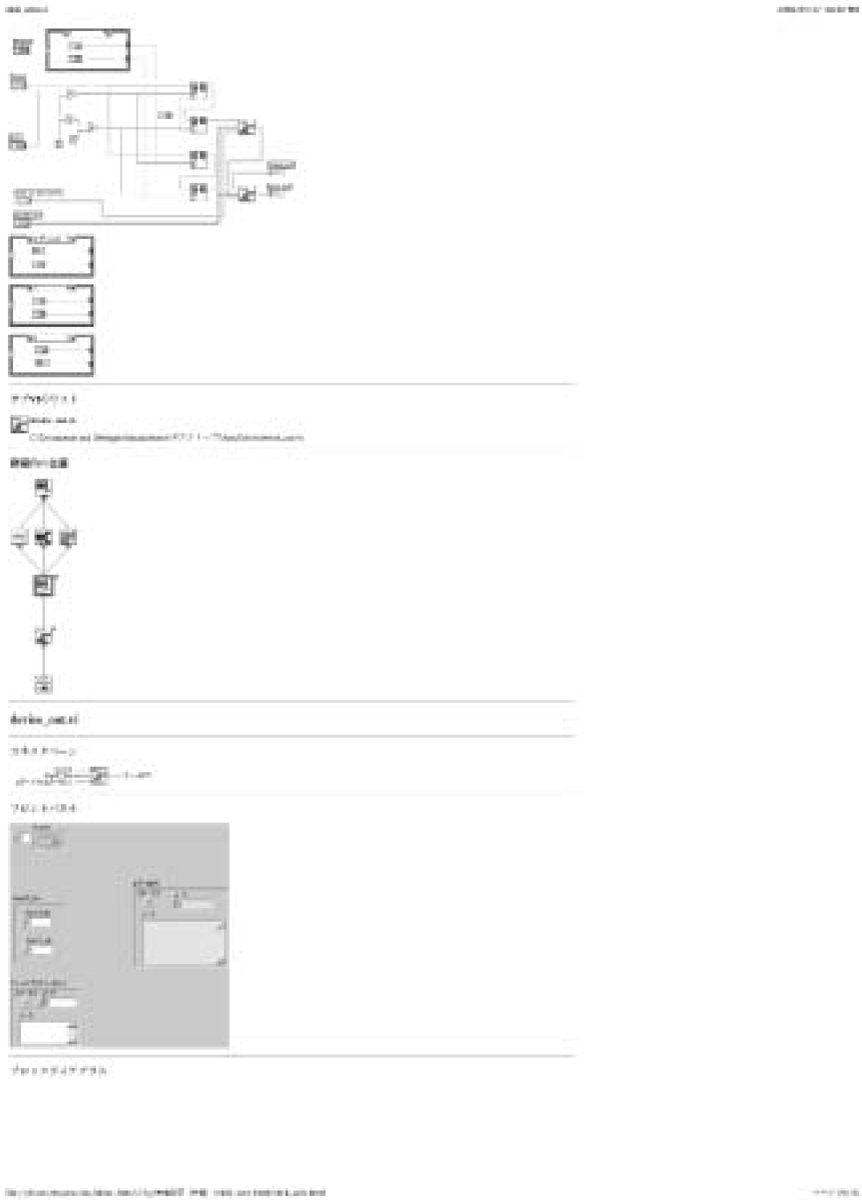


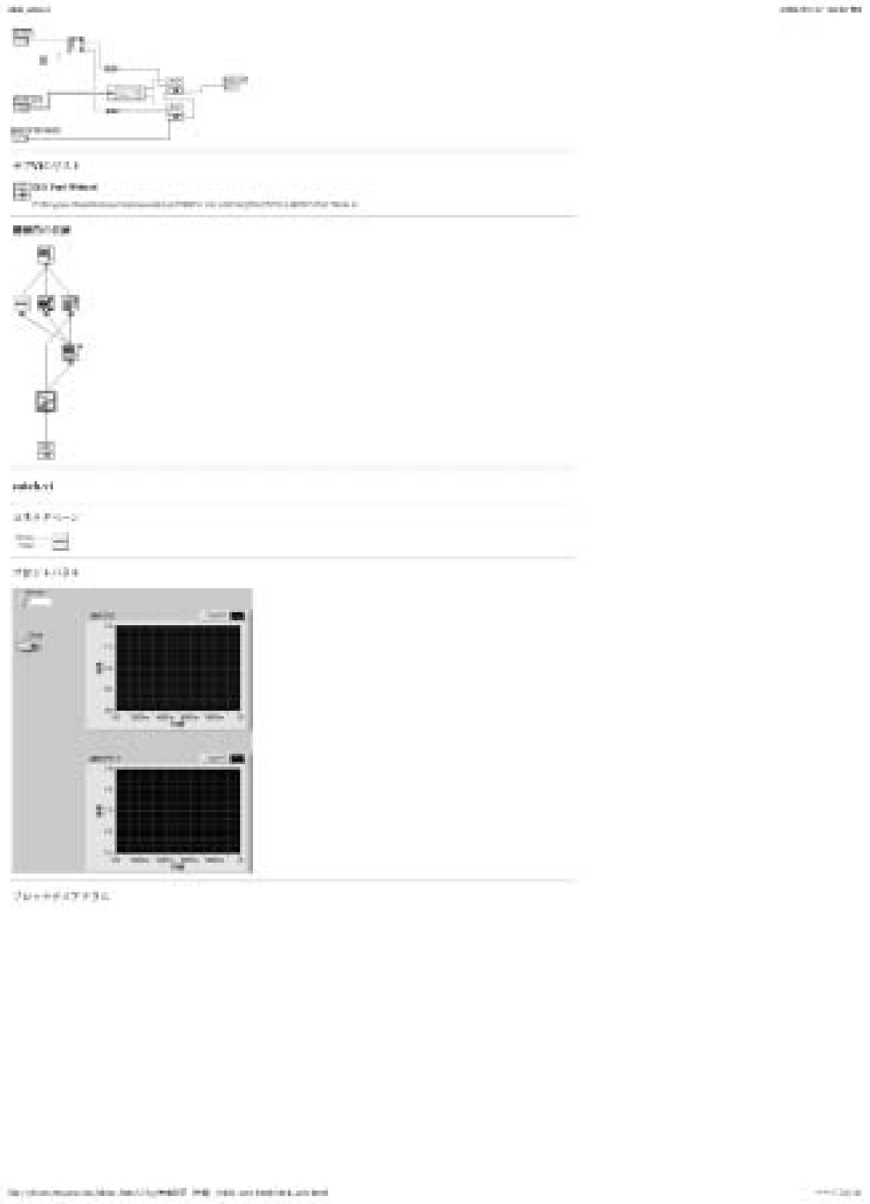


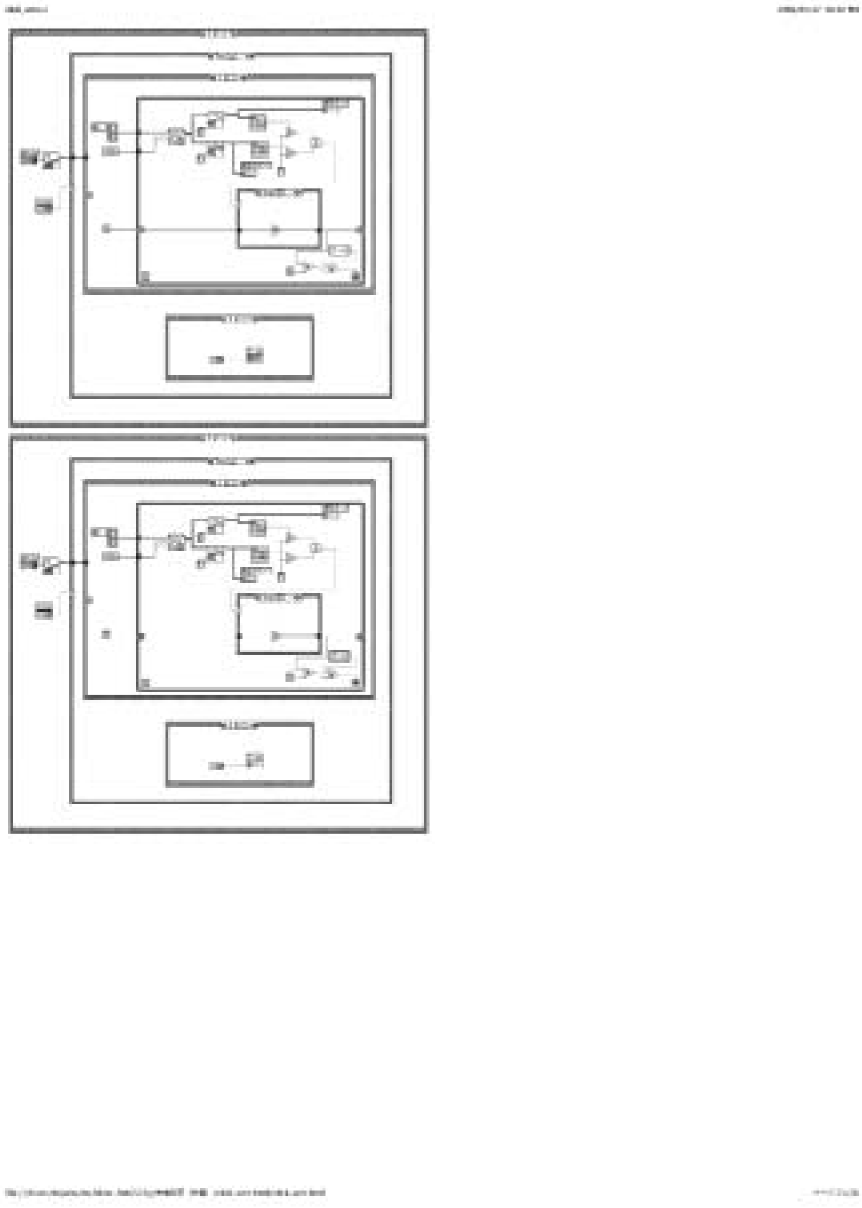


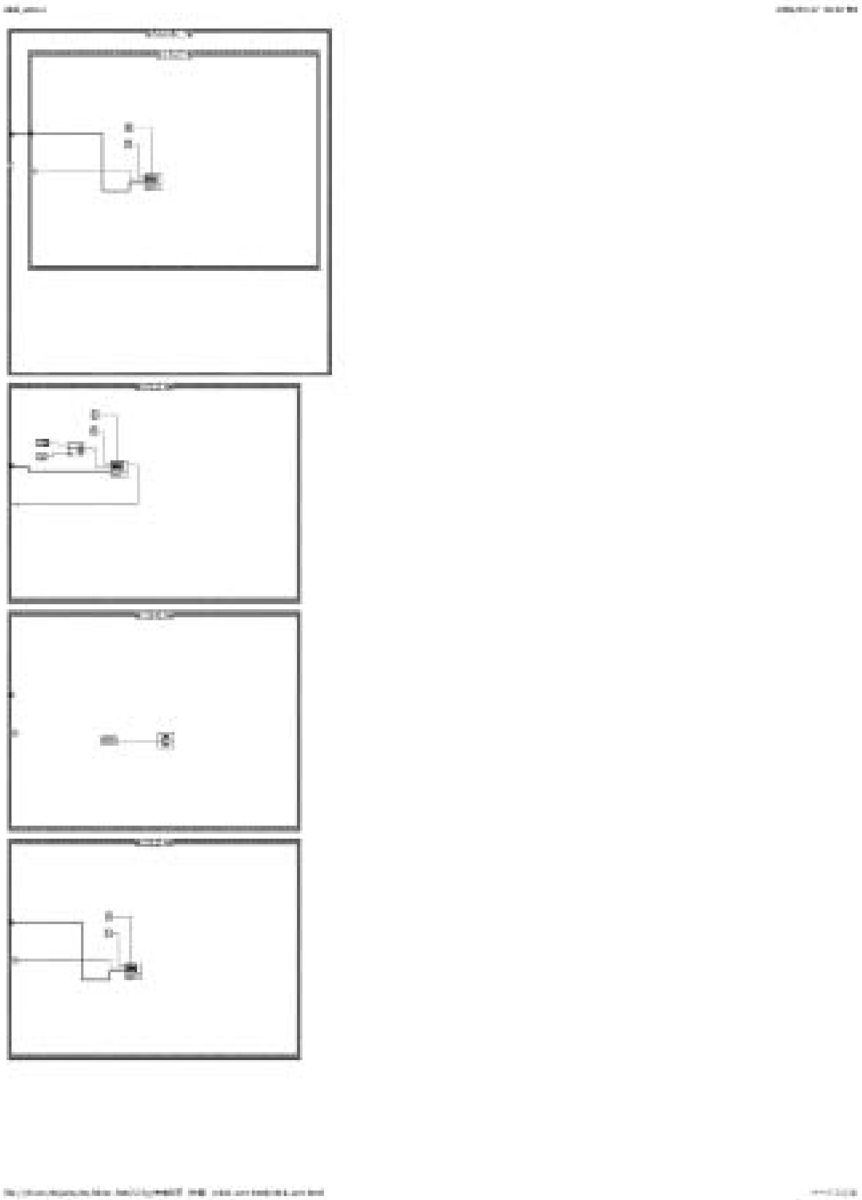


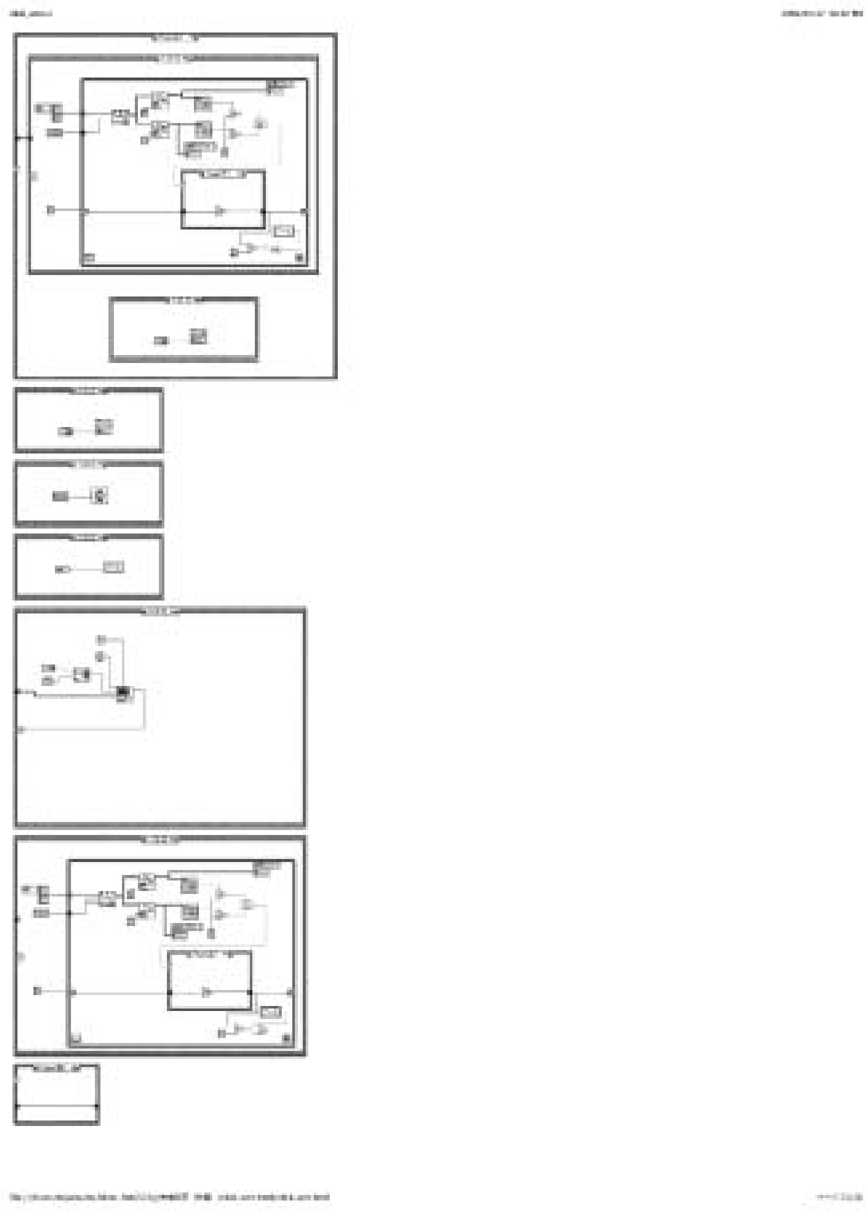


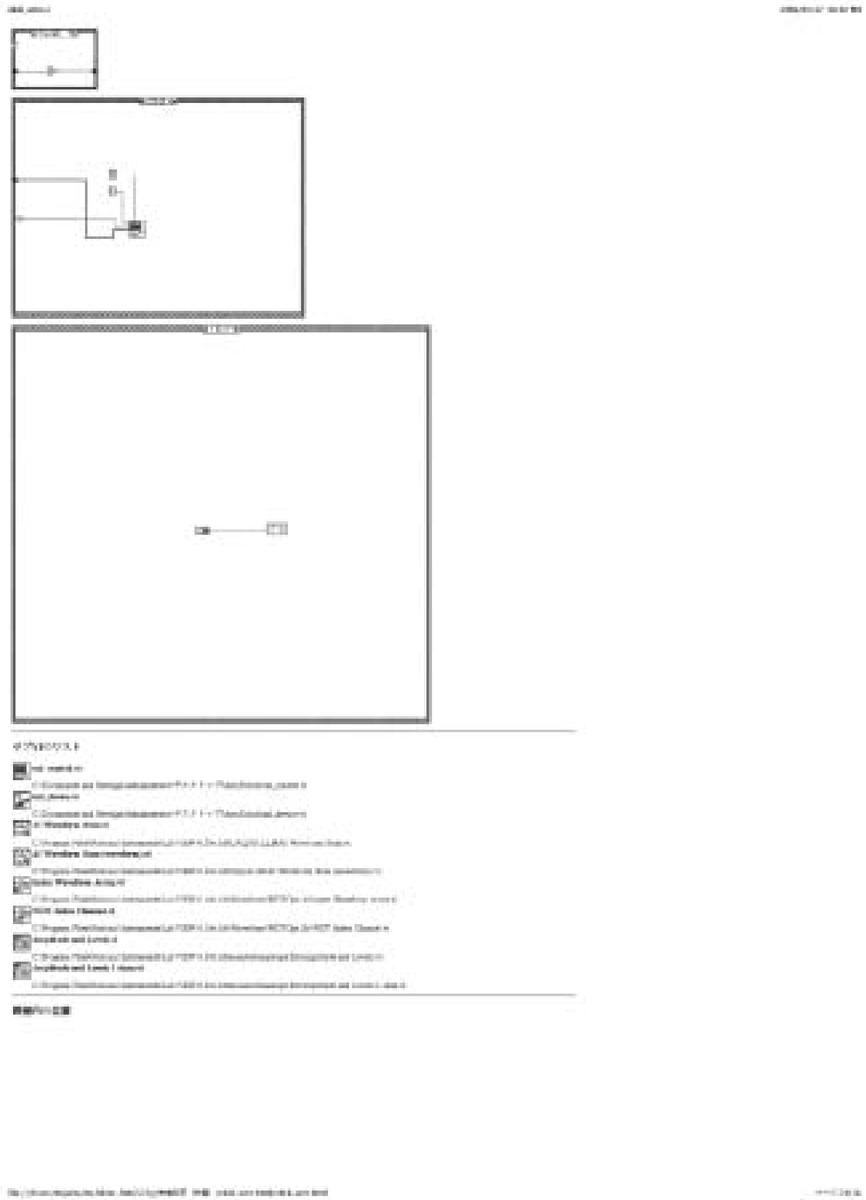


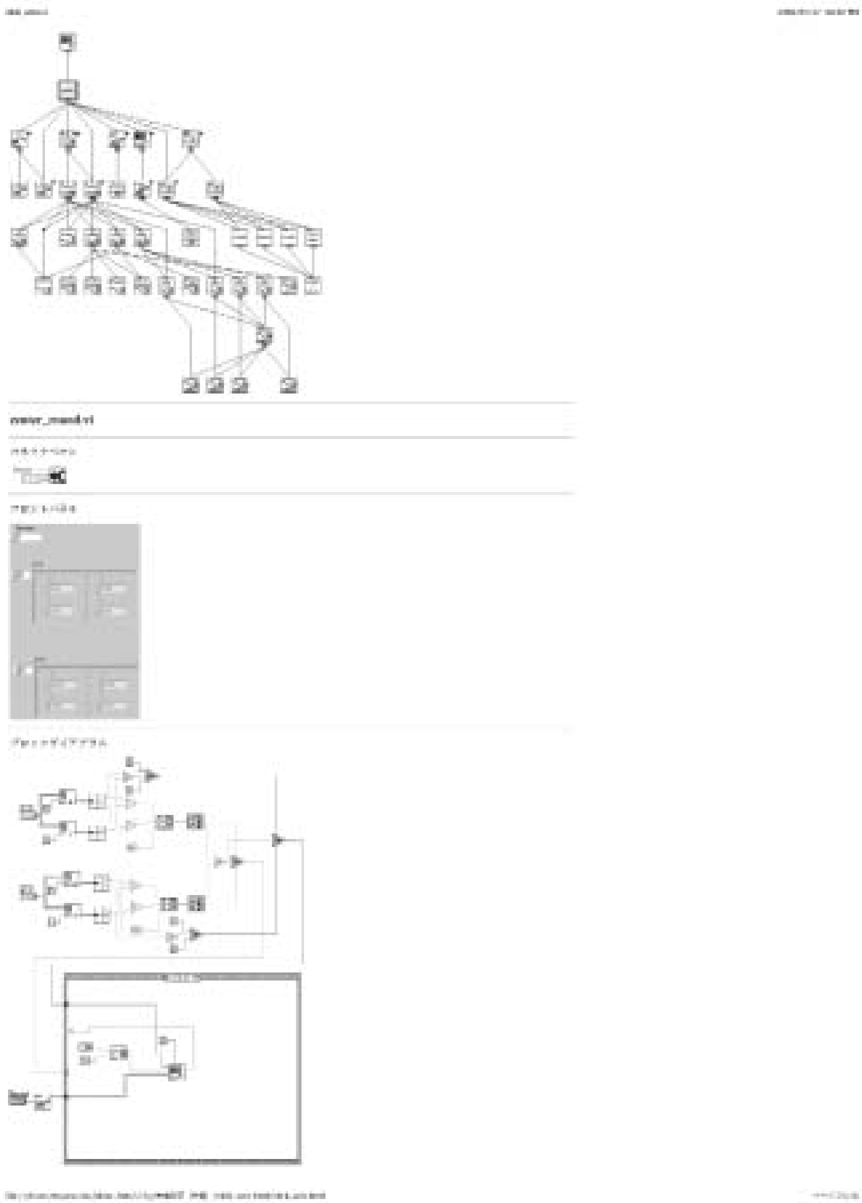


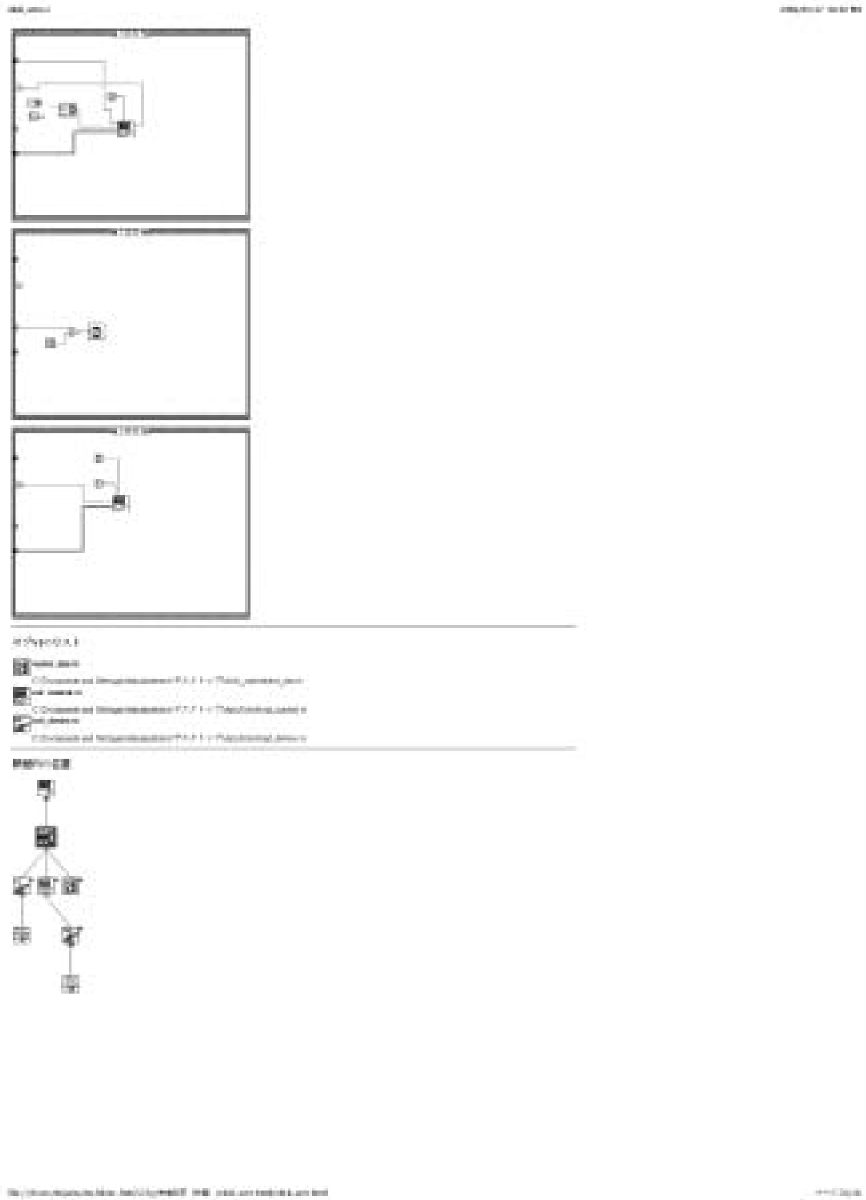












Appendix F The front panel of "Remote control VI for a robot-arm (*control-button system*)". The robot-arm is operated with the control buttons attached to the front panel of the VI that is mounted on a remote browser. We omit to show the block diagram.