A HARDWARE PLATFORM FOR AN AUTOMATIC VIDEO TRACKING SYSTEM USING MULTIPLE PTZ CAMERAS

A report of project-in-lieu-of-thesis
for masters degree

The University of Tennessee, Knoxville

Hongsheng Zhang
June 2002

Abstract

Video tracking is a technique that is used to detect and track objects based on some typical features of the objects, and monitor their activities by image sequences taken by video cameras. Video tracking can be used in many areas especially in security-related areas such as airports, embassies, and battlefields. Mach research has been done with various hardware environments; most based on fixed position still cameras. In this report, we proposed a hardware platform for a video tracking system based on Pan-Tilt-Zoom (PTZ) cameras. The goal of this work is to realize a prototype of a video surveillance system, which can provide high-end video tracking functions based on a mobile server platform. The system consists of three PTZ cameras, frame grabber, Pentium 4 PC, and optional wireless transmitter and receiver for video and data communication. Camera controlling software has been implemented in Visual C++ to control the cameras. Some basic camera functions such as panning, tilting, zooming, focusing, AGC, ALC, etc., have been implemented. Although we can only control one PTZ camera at a time, it is easy to achieve camera handover using camera ID identifier and camera position parameters. We tested the system with both cable connection and wireless connections. With wired communication, the range for the system is at least 200 feet. For wireless communication, the working distance is about 50 feet with the current wireless transmitter and receiver. We also tested the system with our tracking algorithm. The results show that the system can provide a good hardware environment for the tracking algorithm. The camera mounting system is designed to make the whole system easily to move and be setup. The complete system is inexpensive, and is very suitable for application in airport security.

TABLE OF CONTENTS

1 Introduction

It is now well accepted that vision will play a major role in both supervised and unsupervised operations for the automation of several security activities [1] [2]. The purpose of video tracking is to stabilize the line-of-sight (LOS) of a camera to the actual LOS of a moving target, such as a moving human[3]. Video tracking, by definition, is to track moving objects using some typical features, and monitor their activities by image sequences taken by video cameras. Using video tracking, we can answer some questions such as who are they, what are they doing, and where and when they are acting [4].

Traditionally, surveillance systems are mainly realized by device which include sensors such as infrared sensors which are sensitive to pressure variations in a closed room and electronic contact sensors which react when a door is opened for example [5]. Nowadays, more visual surveillance systems are gradually springing up. The video-based surveillance system generally employs one or more cameras connected to a set of monitors. This kind of system realized man's desire of "seeing is believing". However, this video surveillance system needs a person to sit before a monitor to monitor the interested objects, while camera output is recorded to tapes for future investigation. It is a heavy burden let surveillance staff gazes at lots of screen for a long time. Especially for more surveillance sites, surveillance staff lives up to perfect and full scale surveillance [6].

While video tracking systems can provide 24 hour continuous monitoring and analysis the real time video data to achieve the same purpose [7]. Using automatic video tracking system, crime can be detected in real-time. When a crime occurs, the system can send an alarm signal to alert security staff. This can save time and human labor. Investigators do not need to find a useful hint from a large quantity of recorded tape to see what happened.

Video tracking systems can be used in many areas such as airports, embassies, battlefields, robots controlling and even in the classroom or living room. For an example, a video tracking system can be installed in an airport to collect the pictures of people entering and exiting the building so that a potential suspected terrorist can be found in the airport before boarding. Real-time information from the battlefield can improve the situational awareness of commanders and staff [6]. In remote education, a camera can track the face of the instructor. For robots industries, real-time video tracking systems can send commands to robots to perform some difficult tasks [8] [9].

There are a number of research groups that are working on video tracking projects. We can classify those systems into categories, according to their sensor types (single or multiple camera, color or gray scale), and their functionality (tracking single person, multiple people, area of use), as shown as in Table 1.

W4 [4] uses multiple gray-scale cameras to track multiple people. It is designed for outdoor surveillance tasks, and particularly for nighttime or other low light level situations. W4 can recognize events between people and objects, such as depositing an object, exchanging bags, or removing an object. This system runs at 25 Hz for 320x240 resolution images on a 400 MHz dual-Pentium II PC.

A network-based intelligent surveillance system was developed by Tsinghua university [5]. It employs multiple fixed cameras to track multiple people. The PC network reduces the cost of every detection computer. The whole system can be connected using a local area network, and is designed for outdoor use. The frame grabber used can capture 25 frames per second and can be connected up to 4 cameras.

The Easyliving system is designed for indoor application [10]. It uses several PTZ cameras to track people in a living room. The goal of the system is to develop an intelligent environment that facilitates the unencumbered interaction of people with other people, with the computer, and with devices.

The integrated Visual Interface for Gestures and behaviOUR (VIGOUR) [11] was designed as a platform for investigating visually mediated interaction methodologies. The current system uses a single PTZ camera as its only input. VIGOUR tracks behaviors using gestures and head pose to produce a high-level behavior representation, for subsequent interpretation. The system is able to track three people and recognize their gestures simultaneously in real time.

System	Research group	Area of use	Sensor	Camera	Tracking people
W4[4]	University of Maryland	Outdoor	Grayscale	Multiple	Multiple in group
Network ISS [5]	Tsinghua University	Outdoor	Fixed color	Multiple	Single
Easyliving [10]	Microsoft research Vision technology Group	Indoor	PTZ color	Multiple	Multiple
VIGOUR [11]	Queen Mary and Westfield College	Indoor	PTZ color camera	Single	Multiple
Head tracking [12]	Kyoto University	Indoor	PTZ color	Single	Single
VSAM [6]	Robotics Institute, CMU	Outdoor	PTZ color and fixed color	Multiple	Multiple
AVTS	IRIS of UTK	Indoor	PTZ color	Multiple	Multiple

Table 1. Existing video tracking system

The human head tracking system employs a fixed PTZ camera to acquire image sequences [12]. This system is designed for classroom application. The head of the lecturer is always in the center of the image. The average computational time for head detection by this system is about 200 milliseconds for one image whose size is 320 x 240 pixels.

The video Surveillance and Monitoring (VSAM) project that was developed by CMU allows a human operator to monitor activities over an outdoor area using a network of active video sensors [6]. This system can detect and track multiple people and vehicles within cluttered scenes and monitor their activities over a long period of time. The whole system can be installed on a moving van. This system is very similar to our system. The difference is that their system is for outdoor application, and our system is suitable for indoor application, especially an airport.

A plan was developed for a wireless, pan-tilt-zoom (PTZ) camera-based video surveillance system. The goal of this work is to realize a prototype of a video surveillance system, which can provide high-end video tracking functions based on a mobile server platform. The above mentioned video tracking functions include; (i) flexible camera position by wireless video and data transmission, (ii) wide range of search areas by multiple PTZ cameras, (iii) extracting a suspicious person out of complicated background, such as a crowd of multiple people with non-stationary background, and (iv) dynamic analysis of the trajectory of a suspicious person by the inter-camera object handover technique.

The remainder of this paper is organized as follows: Chapter 2 describes the background and related techniques. An overview of the whole system including the functional and hardware block diagram is introduced. The second part focuses on image acquisition. Some specifications for the camera will be described in this chapter, and then some video data formats will be discussed. Since we use NTSC video format as input to the system, NTSC is emphasized. The frame grabber, as an important part of image acquisition, is described. This includes some basic theory for the frame grabber and specifications for the Matrox meteor-II frame grabber. The third and fourth parts describe image data and control data communication. The communication standard will be discussed in this chapter. Specifications for the wireless video transmitter and receiver and data transceiver will also be provided. Chapter 3 explains the basic structure of camera control software that is written in Visual C++. Interface and implementation of camera function will be described. Chapter 4 presents a system integration and performance evaluation. In this chapter, we discuss a possible camera mounting system. The installation and operation manual will also be described. Chapter 5 provides experimental results with algorithm using the proposed system. Finally, Chapter 6 concludes with a summary of the system and future plans.

2 Background and Technical Specifications

2.1 System Overview and Multiple Camera Interface

The goal of this project is to achieve a wireless automatic, real-time video tracking system. Video tracking involves image processing technology such as moving objects detection, feature detection and matching, and tracking. The main features of this system are as follows:

- Images captured by multiple PTZ cameras
- Wireless communication for both video signal and PTZ camera control data signal
- Manual control by controller or remote controlled by computer
- Hardware environment for tracking multiple people
- Suitable for airport application

This system consists of several modules as shown in Figure 1. The first module is the image acquisition module. The PTZ camera completes this function. The next stage is digitization. Since computers deal with digital signals, the NTSC video signal has to be digitized before they are input to the computer. The digitized image will be input to the computer for image processing. The Image processing module includes three sub-modules: the background generation module, segmentation module and tracking module. The main algorithm of this system will be completed in these three modules. We store background information taken by the PTZ camera in the background generation module. Then we compute the difference between the input image and the background
image to detect the moving image. This method is known as background subtraction. The moving image is segmented by segmentation module. Only the segmented image will be sent to the tracking module. This decreases the amount of data, thus saving computational time. The tracking module will detect the position and size of the object and generate a command sent to the computer through a communication port such as the RS485 data

communication port. The camera can then move according to command to track the object automatically.

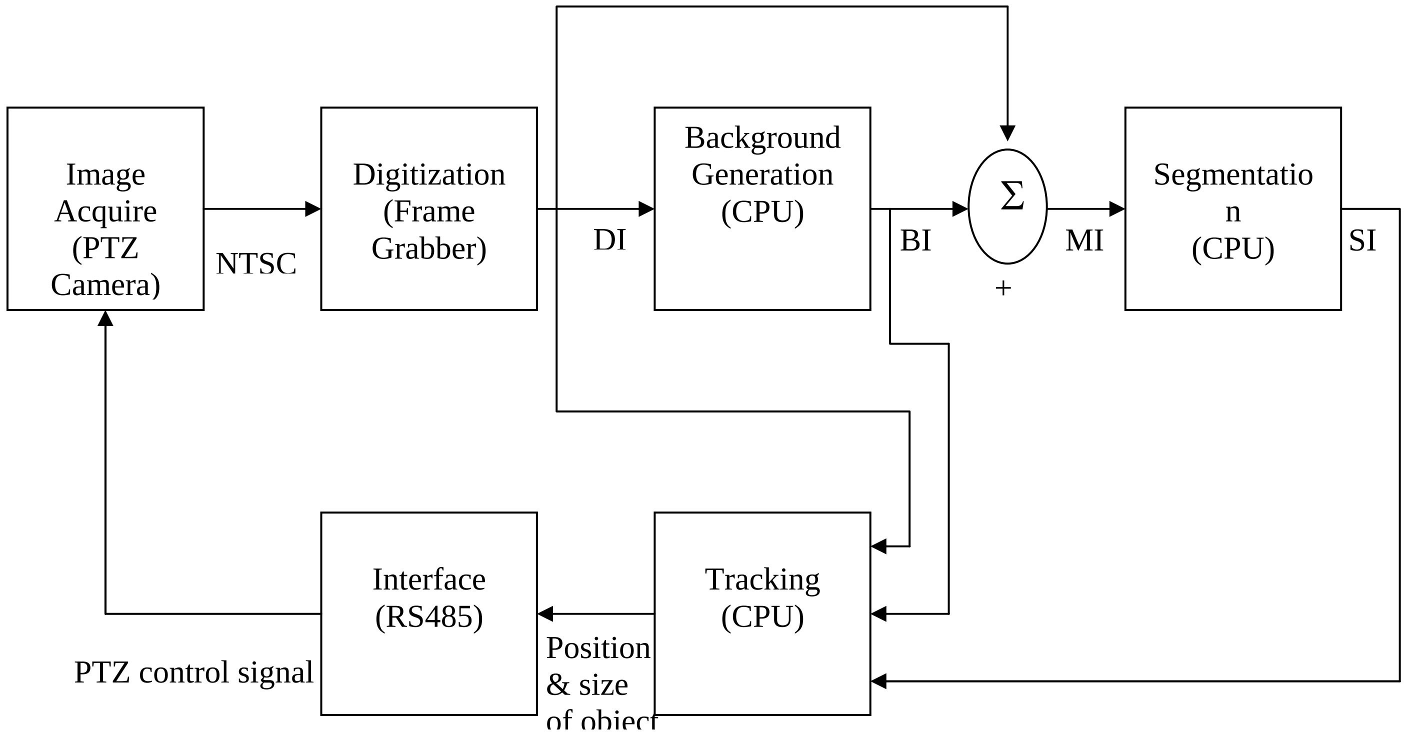


Image Acquire (PTZ Camera)
NTSC
Digitization (Frame Grabber)
DI
Background Generation (CPU)
BI
Σ
+
MI
Segmentatio n (CPU)
SI
Interface (RS485)
PTZ control signal
Position & size of object
Tracking (CPU)

Figure 1. Functional Block Diagram of Real Time Video Tracking System

DI = Digitized Image; BI = Boundary Image;
MI = Moving Image; SI = Segmented Image;

Figure 2 shows the wireless version of the multiple system connection block diagram. The video output of the camera is connected to wireless video transmitter. The wireless video receiver is connected to the video input of the frame grabber. The frame grabber is installed in the computer. The wireless transceiver for data communication is connected to the serial port of the computer (COM1 or COM2). Another wireless transceiver is connected to the communication port of the camera (RS422 or RS485, depends on the camera). For wireless communication, we most consider the performance of the transmitter and receiver. For the wired system, maintaining the strength of the signal is a significant issue. As cable length becomes longer, the signal will decease, use of a signal repeater and a better signal splitter are then necessary.

When controlling three cameras, there are some issues to be considered.

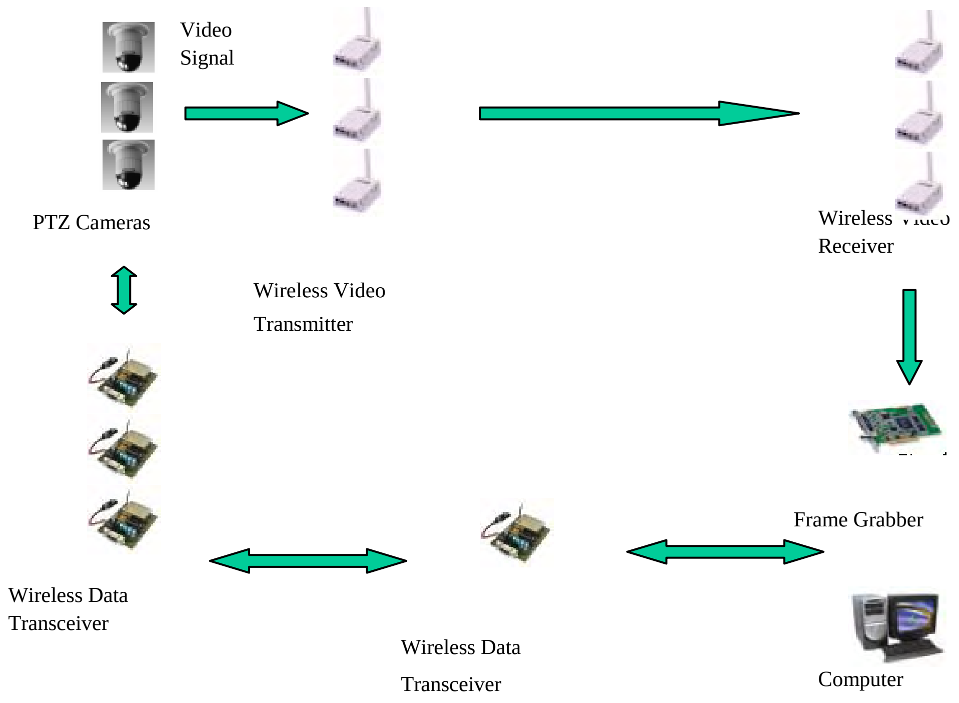

Video Signal
PTZ Cameras
Wireless Video Transmitter
Wireless Video Receiver
Frame Grabber
Wireless Data Transceiver
Wireless Data Transceiver
Computer

Figure2. Wireless multiple camera system

At first, using manual control with the controller, these three cameras should be connected with the controller through a data multiplexer. Figure 3 shows the connection between the camera and controller. We choose a Panasonic WJ-MP 204 as our data multiplexer. The multiplexer can support up to 4 cameras with one WV-CU360 controller. To control a specific camera, a camera ID has to be given to the cameras respectively.

Secondly, for remote computer control, we have to specify the ID of the camera in command. When multiple units are daisy chain connected, a command must have a unit address as shown below.

Ex. Shutter 1/250 ON

STX A D <u>00</u> ; G C 7 : 0 0 2 1 1 0 C ETX

Where 00 is the unit address. Unit addresses can be in the range 00—96 for the WV-CS854 camera[13]. We have solved this problem in our software.

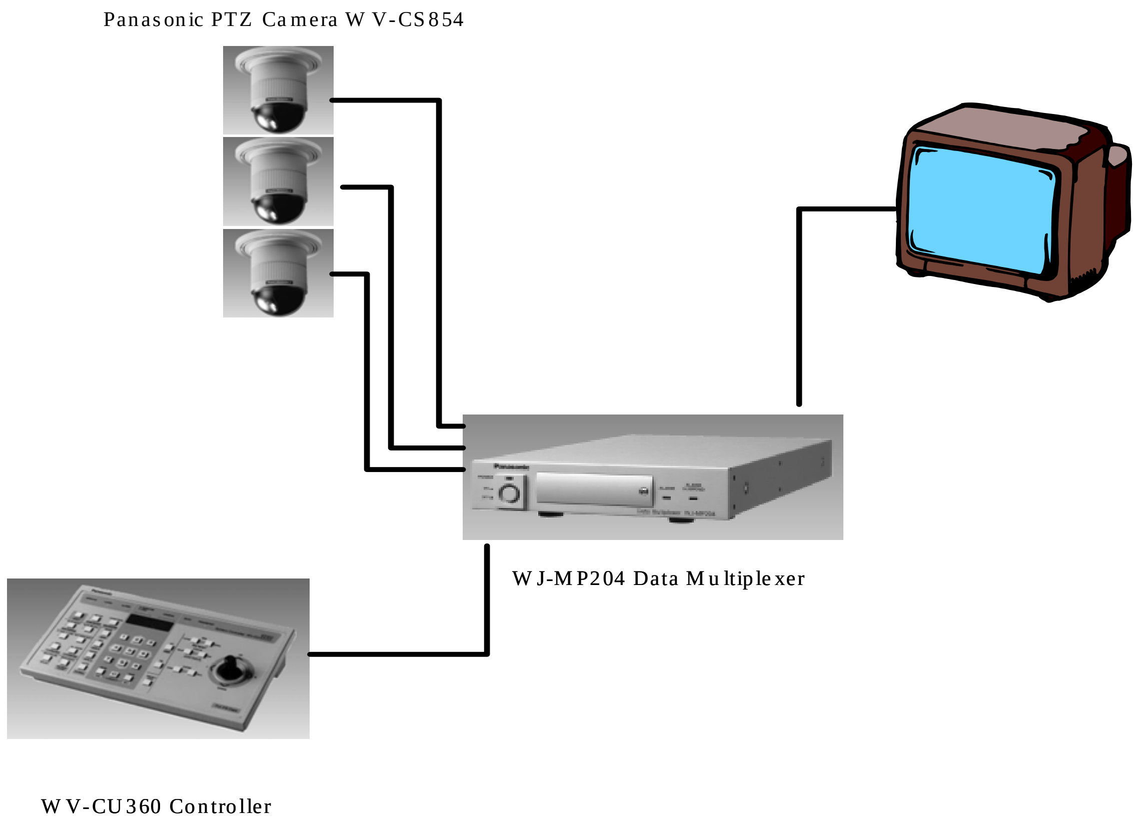


Figure 3. Multiple cameras connection through multiplexer

For the frame grabber, the Meteor-II can be connected to up to 8 analog cameras. But there is a tradeoff. The more cameras connected, the slower the frame rate. For rapid switching between multiple cameras, some software improvement was needed to the frame grabber. For the Meteor-II, The switching time between two cameras can be calculated as follows: The average switching time is equal to one over the typical frame/field rate minus the frame/field time [14]. That is:

For NTSC in frame mode

1/10.8fps – 1/30fps = 63 ms

For NTSC in field mode

1/25.5fps – 1/60fps = 23 ms

Because tracking speed is a very important factor in real-time video tracking system, we need to reduce every possible delay time.

A survey was conducted for the hardware components used in this system. The hardware we choose for this system is as follows:

- Panasonic PTZ camera WV-CS854A
- N2400 wireless transmitter and receiver for video
- DPC-64-RS232 transceiver for the control signal
- Matrox Meteor-II frame grabber
- Dell Precision 330 computer, Pentium 4, 1.3 GHz

The details of the specifications of these components will be discussed in the following sections.

2.2 Image Acquisition

Image acquisition is the first module of the system. The PTZ camera and frame grabber completes this function. In this section, specifications for the camera and image data format will be discussed.

2.2.1 Camera

Since the performance of the camera is very important for our system, we did a survey to camera. For automatic tracking purposes, the camera should follow the tracked object so that we can have a good view of the object. We choose the PTZ camera for our system. Some basic requirements of the PTZ camera is as following:

- Camera can move in any arbitrary direction.
- Possible to control camera by coordinates. Setting and reading camera position by coordinates
- Camera can be controlled by manual controller and can support communication ports such as RS232, RS485 for computer control.
- Can read camera status such as whether the camera is moving or not
- High performance including high resolution, lower illumination limit, high zoom ratio, and etc.
- Panning range should be 360 degrees continuous, tilting angle 180 degrees with digital flip or 90 degrees without flip.

- High panning and tilting speed.

Spec Comparison of PTZ Cameras						
Name	Electra	WebEyeSPD	Spectra II (SD5BC-F0)	Spectra Lite Domes (SD5TAC)	Panasonic WV-CS854	DeltaDome II
Optical Zoom	10x	16x	up to 22x	16x	22x	22x
Zoom Range	4.7 to 51	128x	22x8	16x8	22x10	22x8
Interface	Wireless	Cable	Cable	Cable	Cable	Cable
Price	USD 1995	USD 4500	USD 3030	USD 2233	USD 1495	
Range of rotation	200 Degree	360 Degree	360 Degree	360 Degree	360 Degree	360 Degree
Tilt range	15(up)/-87(Down)	0 to 90	2 to -92	0 ~ 90	0 ~ 90	>90 Degree
Shutter speed	Adjustable	1/60~1/100000s	1/60 ~ 1/30000	1/60 ~ 1/10000	1/60 ~ 1/10000	???
Min. Illumination	<5 lux	3 lux	0.07 lux	1 lux	1 lux at color	0.05 lux
Image Sensor	1/4" CCD	1/4" CCD	1/4" CCD	1/4" CCD	1/4" CCD	1/4" CCD
Iris	Auto/Direct/Hold	Auto	Auto/Manual	Auto/Manual	Auto/Manual	Auto/Manual
PTZ control	RS-232C	RS232	RS422	RS422	RS485	RS422
Focus Control	Auto/Direct/Hold	Auto	Auto/Manual	Auto/Manual	Auto/Manual	Auto/Manual
Resolution (H)	460 TV lines	525 Lines	470 TV lines	470 TV lines	480 lines	525 lines
Resolution (V)	350 TV lines					
Effective Pixels	768(H)x494(V)	410k	768(H)x494(V)	768(H) x 494(V)	768(H)x494(V)	768(H)x494(V)
Focal length	5.5mm to 79.7mm	3.9mm to 62.4mm	4.1mm to 73.8mm	3.9 mm to 63 mm	3.79 to 83.4 mm	4 to 88mm
Panning Speed	Max 120 degree/s	240 degree /s	250 degree/s	250 degree/s	300 degree/s	280 degree/s
Tilting Speed	Max 120 degree/s	180 degree/s	200 degree/s	200 degree/s	300 degree/s	280 degree/s
Power	12 V	12 V	24 V	24V	24V	24V
Dimension (WxHxD)	141 x 114 x 178	6.30"(D)x7.91"(H)			4.43"(D) x 7.5"(H)	4.7"(D)x8"(H)
Weight	1.2 Kg (2.61 lb)	4.6 lb		4.3 lb	4.4 lb	3.2 lb
Suitable	No	No	No	No	Yes	No
Reason	Panning range is not 360 degree	Too expensive	Price reason	Price reason	Large zoom and better price	Not good as WV854

Table 2. Survey of PTZ camera

We investigate various PTZ cameras, and collected their specification. A comparison was made among these cameras according to their main specification such as optical zoom, zoom range, resolution, panning angle, panning speed, tilting angle, tilting speed, minimum illumination, communication interface, price, etc. Table2 shows the survey result.

We finally choose the Panasonic WV-CS854 color dome camera. The WV-CS854 is an all-in-one, high performance color dome camera. The camera incorporates the Super-

Dynamic Digital Signal Processor, pan-tilt mechanism and 22X zoom lens in a compact enclosure. In additional, compared with other cameras with similar performance, the price for this camera is low. Some main features of the camera are as follows:

High quality picture of 755 x 485 pixels

1.0 v (P-P) NTSC composite output

22x optical zoom with 10x electronic zoom function

Endless 360 ° panning range and 180° tilting range

Maximum 300 °/s panning and tilting speed

RS485 communication port with half or full duplex selection

2.2.2 Image Data Format

Since we are dealing with video output from the camera, only the video signal format will be discussed here. Video data usually refers to a one-dimensional analog or digital signal of time. Traditional analog form data is used to record, store and transmit video signal. In the last decade, the digital form of data has been developed very fast. The analog video standard includes component analog video, composite video and s-video. These standard have different image parameters and handle color in different ways. In component analog video (CAV), each primary is considered as a separate monochromatic video signal. The primaries can either be R, G, and B signals or luminance-chrominance transformation (YIQ). Where the luminance component (Y) represents the gray level of the video, and the chrominance contains the color information. Chrominance representations change with different standards. The CAV representation yields the best color reproduction, but it is difficult to transmit since the synchronization the three components and it takes three times more bandwidth. The composite video signal format encodes the chrominance component on top of the luminance signal for distribution as a single signal that has the same bandwidth. Different composite video standards are used in different countries. These are the NTSC (National Television Systems Committee), PAL (Phase Alternation Line), and SECAM (Systeme Electronique Color Avec Memoire). The NTSC composite video standard is currently used in North America and Japan. The NTSC signal is a 2:1 interlaced video signal with 262.5 lines per field (525 lines per frame), 60 fields (30 frames) per second, and a 4:3 aspect ratios. PAL and SECAM are mostly used in Europe today. They are also 2:1 interlaced, compared with NTSC, they have a different resolution, and higher bandwidth. Both have 625 lines per frame and 50 fields per second. All digital video signals use component representation of the color signal. Most color video cameras provide RGB output that are individually digitized. There are also some digital video standards such as CCIR601 for both 525 line and 625 line TV systems. The CCIR (International Consulative Committee for Radio) defines this standard for international exchange of production-quality programs. It is based on component video with one luminance (Y) and two color difference signal. The raw data rate for the CCIR601 format is 165 Mbps. Because this rate is too high for most applications, the CCITT (International Consultative Committee for Telephone and Telegraph) has proposed a new digital video format, called the common International Format (CIF). The CIF format is progressive, and requires approximately 37 Mbps. There are some other standards in the computer industry for display video, such as VGA (640pixels/line x 480 lines) and S-VGA (1280 pixels/line x 1024 lines or 1024 pixels/line x 768 lines). Figure 4 shows the difference between an interlaced and non-interlaced video signal in terms of frame.

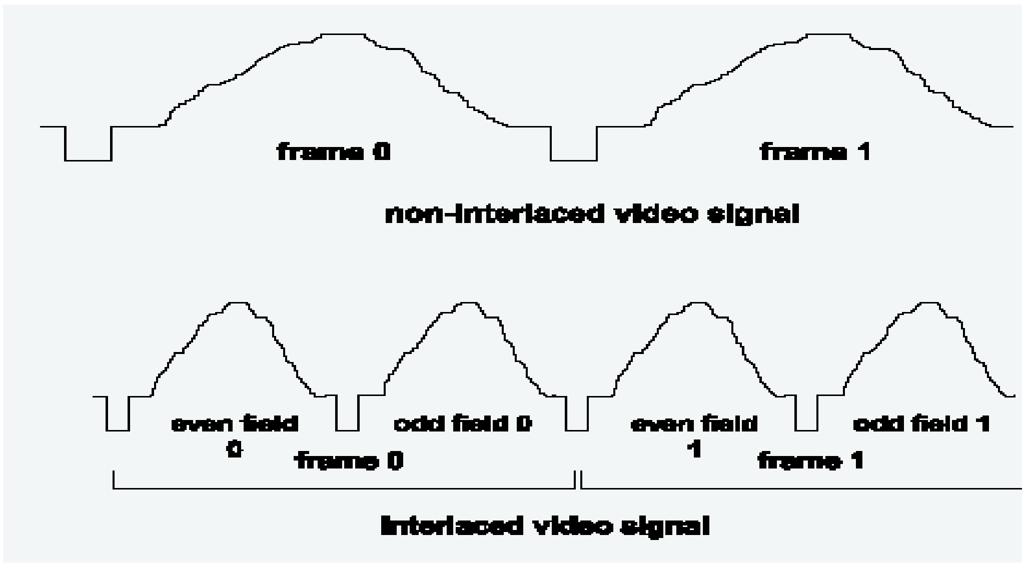


Figure 4. Frames of non-interlaced, interlaced video signal [15]

2.2.3 NTSC Standard

NTSC stands for National Television System Committee, which devised the NTSC television broadcast system in 1953. NTSC is also commonly used to refer to one type of television signal that can be recorded on various tape formats such as VHS, 3/4" U-matic and Betacam.

The NTSC standard has a fixed vertical resolution of 525 horizontal lines stacked on top of each other, with varying amounts of "lines" making up the horizontal resolution, depending on the electronics and formats involved. There are 59.94 fields displayed per second. A field is a set of even lines, or odd lines. The odd and even fields are displayed sequentially, thus interlacing the full frame. One full frame, therefore, is made of two interlaced fields, and is displayed about every 1/30 of a second. The frame rate is 29.97 frames per second (0.1% slower than the original 30 frames per second, to avoid interference with the color subcarrier part of the NTSC television signal). In contrast, computer video usually runs at 30 frames per second, since it does not use NTSC.

Each frame is made up of two fields, with the second field writing between the lines of the first to provide more displayed lines per frame (the persistence of the CRT phosphor is long enough that the first field remains displayed while the second is being written).
Each frame is made up of 481 horizontal lines (240.5 lines per field) that are visible (sometimes called "active") plus another 44 lines (22 per field) that are blanked (the electron beam is turned off), since they occur while the scanning beam returns to the upper-left corner of the screen. This makes a total of 525 lines per frame.

Such interlaced scanning was necessary to fit the screen resolution desired into the video bandwidth available. Newer technologies (such as computer monitors and HDTV) usually use noninterlaced (also called progressive) scanning. The term "NTSC" is also used to refer to the standard video signal that is used (for example) between a videocassette recorder (a standard home VCR) and television (it uses what is often called an RCA connector).

When broadcasted, an NTSC signal requires a 6-MHz bandwidth. That is, channel 2 is 54 to 60 MHz, channel 3 is 60 MHz to 66 MHz, and so on. To reduce interference, adjacent television channels (for example, channels 3 and 4) are not assigned in the same coverage area, and the transmitting antennas of transmitters that are assigned to the same frequency must be at least 155 miles apart.

For each 6-MHz channel:
The main (sometimes called video) carrier frequency is 1.25 MHz above the base frequency (of 54 MHz for channel 2, for example--so the video carrier is at 55.25 MHz). This carrier is amplitude modulated (AM) by the composite video signal (which has all of the picture and synchronization information).

The (left+right) sound information is sent by frequency modulating (FM) a sound subcarrier that is 4.5 MHz above the video carrier frequency (so the sound for channel 6 is at 87.75 MHz--which explains why you can usually hear broadcast TV audio on a standard FM radio, since FM starts just above this, at 88 MHz).
For stereo signals, an FM left-right audio signal is also sent, at a pilot frequency above the sound subcarrier.

Standard television has a 4:3 (horizontal:vertical) aspect ratio. Regular monochrom*e* (black-and-white) television broadcasts began in 1936 in Britain and in 1939 in the U.S.

2.2.4 Frame Grabber

The frame grabber is the interface between the camera and computer. A frame grabber can digitize the analog color video signal from the camera, and input these digitized video signals to the memory of the computer.

There are two elements required to acquire images. The first is a physical sensor that is sensitive to a band in the electromagnetic energy spectrum (such as the x-ray, ultraviolet, visible, or infrared bands) and that produces an electrical signal output proportional to the level of energy sensed. The second, called a digitizer (such as a frame grabber), is a device for converting electrical output of the physical sensing device into digital form. There are many kinds of sensors. The most widely used now are solid-state arrays, for example, CCD sensors and CMOS sensors. They all contain an array of photosites that can transform optical signal to an electrical voltage signal. The amplifier outputs a voltage signal proportional to the contents of the row or area of photosites. The image signal outputted from the sensors must be digitized for image processing. Depending on the type of the output, there are several kinds of frame grabbers such as standard, non-standard, digital and high-end frame grabbers. Standard frame grabbers are able to digitize video standard signal as CCIR (the European standard for mono-chrome signal), EIA (the US equivalent), PAL (the European standard for color signals) and NTSC (the US equivalent). Digital frame grabbers work for digital signal form digital camera. The non-standard frame grabbers work for non-standard camera such as trigger camera and cameras with an asynchronous shutters. High end frame grabber are used for rather special solutions such as the enormous amount of computing power which is required in case of real-time image processing. For example, Matrox Genesis solves this problem with the aid of on-board signal processors.

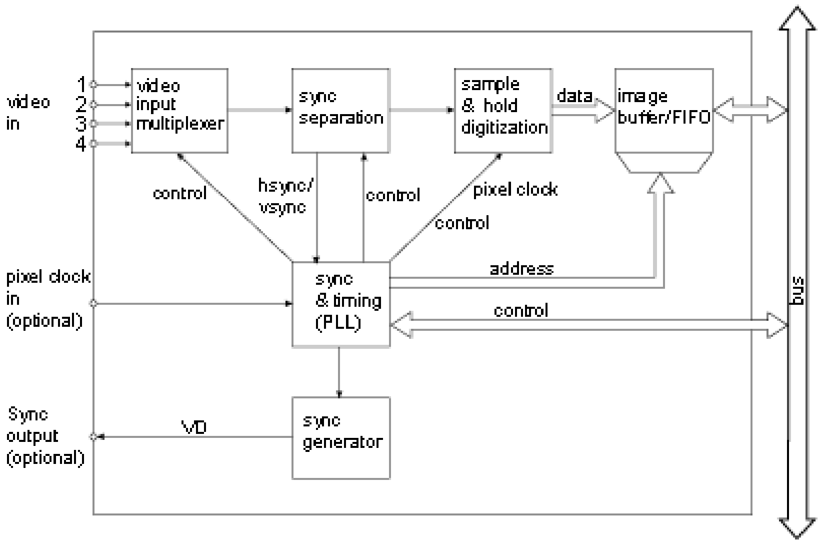


Figure 5 Basic Structure of a frame grabber [15]

Figure 5 shows the basic structure of a frame grabber. First of all the sync separation separates the synchronization pulses from the incoming video signal. The horizontal sync (hsync) indicates the beginning of a new line and vertical sync (vsync) the beginning of a new field or frame. After a stable synchronization of the lines and frames has been achieved, the next step is to generate the pixels. In accordance with the video standard, the sample and hold unit takes pixels per line to digitize them. The digitized pixels are collected in an image buffer or FIFO buffer. The image buffer stores at least one complete frame and is used in case the bandwidth of the bus is too small to transport the digitized video data without loss. The PCI bus is so fast that it is possible to collect the digitized video data directly in the main memory of the computer and pass it directly to the graphic card to view it in real time.

Spec Comparison of Frame Grabber					
Name	Matrox Meteor-II	Matrox Meteor-II/Multi-Channel	Matrox Orion	Matrox Genesis-LC	NI PCI-1411/PXI-1411
price	USD 595	USD 895	USD 945	USD 1995	USD 895 / 1095
Input Type	NTSC	Standard/RGB	Standard/RGB	Standard/Non-standard	Standard Color
Internal Buffer	4 MB	4 MB	32 MB	6 MB	16 MB
Speed	30 fps	30 fps	30 fps	30 fps	30 fps
DSP Board	No	No	No	Yes	Yes
Sampling Rates		up to 30 MHz		up to 140MHz	12.27 MHz
Pixel Jitter	4-5 ns	1.5 ns to -1.5 ns	4-5 ns		
Suitable	Yes	No	No		
Reason	Work for NTSC	Not work for NTSC	Not work for NTSC		
Name	NI PCI-1409	DFG/LC4	Matrox meteor-II/DIG	Matrox Meteor-II/1394	Matrox Corona
Price	USD 1195	USD390	?	?	?
Input Type	Standard/Non-standard	NTSC	Digital	Digital	Standard/non-standard
Internal Buffer	16 MB	FIFO	4MB	4 MB	8 MB
Speed	30 fps	30 fps			
DSP Board	Yes	No	No	No	Yes
Sampling Rates	25.8 MHZ	40 MHz			12.27 MHz
Pixel Jitter	<2 ns	<6ns			
Suitable		No	No	No	No
Reason		Not famous	Work for digital	Work for Ieee1394	Not for NTSC

Table 3. Survey result of frame grabber

The main specifications for the frame grabber are input type, process speed, numbers of inputs, the size of the input buffer, etc. We surveyed several kinds of frame grabber based on these specifications. Table 3 shows the survey result.

We choose Matrox Meteor-II frame grabber. The main reason for this choose is that this frame grabber supports color NTSC input that is the output of the PTZ camera (WV-CS854), and also supports multiple inputs to one frame grabber. The price is also good. One more important reason is we have used this frame grabber and its related software library, which should can save time.

Main features of the frame grabber are as follows:

- Capture from NTSC, PAL, CCIR and RS-170 video sources
- Up to 8 analog standard inputs
- Real-time transfer to system or VGA memory
- Extensive 4M buffer for reliable capture
- Power output and RS232 serial interface
- Available powerful software support

2.3 Image and Data Communication

For image and data communication, our system was configured for both wireless and wired communication. For wireless communication, we need the wireless transmitter and receiver work for both the video and control signals. The main specification for the wireless transmitter and receiver are working frequency, channels, working distance, input and output type.
There are some wireless working frequencies standards. Commonly used frequencies are: 900 MHz, 2.4 GHz, and 5.8 GHz. Since so many devices are using 900 MHz, to avoid the interference, we choose those transmitter and receiver working for 2.4 GHz. Since our system will be installed in airport, the distance is not a big problem, but for better result, we choose the working distance around 2 miles.

2.3.1 Wireless Communication

We checked various wireless transmitters and receivers for both video and control signal. We compared them according to their working frequency, working distance, input and output type and price. Table 4 shows the result of the survey. AT the beginning, we tried to find device that would work for both video and control signal. Some of them are very

Spec Comparison of Wireless Transmitters and receivers						
Name	PTZ-900 Transmitter	PTZ-900 receiver	Channel Tr & Re	HP 2.4GHz 4 Ch. Tr & Re	Premier AG-1400	Premier AG-1525
Frequency	902.2 MHz	902.2 MHz	2.4 GHz	2.4 GHz	2.4 GHz	5.8 GHZ
Distance	up to 12 miles		300 to 600 ft	1500 to 3000 ft	<0.4 mile	<1 mile
Price	USD 2173.95		USD 169.95	USD 229.95	?	?
Input Type	RS232,422/485		Video	Video	Video and data	Video and data
Output Type		RS232,422/485			RS422/RS485	RS422/RS485
Application	Control Signal		Video	Video	Video and data	Video and data
Suitable	No	No	No	NO	No	No
Reason	Expensive	Expensive	Only for Video	Only for Video	Short distance	Short Distance
Name	Premier AG-1450	N2400	CW9900TX+ CW7800RX	DPC-64-RS232 Transceiver	Rtcom-RS232 Transceiver	RTCom-Globle Transceiver
Frequency	2.4 GHz	2.4 GHz	2.4 GHz	433.92MHz or 418 MHz	433.92MHz or 418 MHz	464 ~ 466 MHz
Distance	< 2 miles	1500 feet	700 feet	500 feet	400 feet	500 Meter
Price	USD6000	USD314.00	USD368	USD178.86	USD247.90	USD514
Input Type	Video and data	Video(4 channels)	Video	Control data	Control data	Control data
Output Type	RS422/485	NTSC	NTSC	RS232	RS232	RS232.RS422,RS485
Application	Video and data	NTSC	NTSC	PTZ Control	PTZ Control	PTZ Control
Suitable	No	Yes	No	Yes	No	No
Reason	Price is too expensive	Distance and price are good	Price and size	Distance and price are good	Price and distance	Price

Table 4 Survey for wireless transmitter and receiver for video and control data

good for our purpose, but very expensive. We choose the less expensive but good quality N2400 wireless transmitter and receiver for video signal and the DPC-64-RS232 FM transceiver module for control data. The sizes of both are small, and this makes it easy to assembly the wireless equipment to the whole system. Figure 6 and Figure 7 show the actual size of the transmitters compared to a cigarette box.

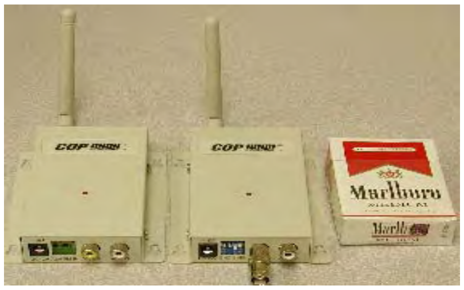


Figure 6. N2400 video transmitter

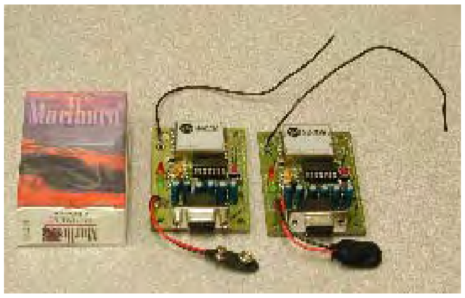


Figure 7. DPC-64-RS232

The main features of the N2400 wireless video transmitter and receiver are as follows:

- Working frequency is 2.4 Ghz
- 4 channel for more inputs
- Transmit and receive video with audio
- Transmit and receive both black & white or color video
- Up to 1500 feet line of sight with internal antenna. 4 miles with 24 db antenna
- Small size, only 115mm x 23mm x 80mm

Since we need to control the PTZ camera and receive the feedback from the camera, we choose transceiver for control data communication. Otherwise, we have to buy 2 sets of transmitter and receiver. We check some device, but for the price reason, we choose DPC-64-RS232 intelligent FM transceiver module for our system. Some main features of it are shown as follows:

- Up to 9600 bps data rate
- 500 feet open field range
- 433.92 MHz or 418 MHz FM operation
- Transparent data encoding and decoding
- Half duplex RS232 communication

- Automatic error checking

2.3.2 Data Communication Standard

On our computer, there is often at least one serial port for data communication. There are four kinds serial port now. They are: RS232, RS422, RS423, RS485. Since in our project, we will deal with some data communication, it is necessary to understand the concept of these standards. In this paper, a brief introduction and reference are given for these four standards.

Data communication can be affected by many factors such as induced noise, ground level differences, impedance mismatches, failure to effectively bias for idle line conditions, and other hazards associated with installation of a network. Many manufactures have developed their own standard for data communication. The Electronics Industry Association (EIA) has produced standards for RS485, RS422, RS232, and RS423 that deal with data communications to allow transfer data over specified distances and data rates. The “RS” stands for recommended standard. The “RS” standard was previously marked by EIA, the EIA has officially replaced "RS" with "EIA" to help identify the origin of its standards. But many engineer continue to use “RS” instead of “EIA”. Because it is not official standard, many manufacture are trying to develop their own products based on theses standards.

RS232

This standard was developed by the EIA in the early 1960s. It was primarily used with modems. It specified signal voltages, signal timing, signal function, a protocol for information exchange, and mechanical connectors. It remained widely used through the industry. Electronic data communications between elements will generally fall into two broad categories: single-ended and differential. RS232 is a single-ended, it allows the data transmission from one transmitter to one receiver at relatively slow data rates (up to 20K bits/second) and short distances (up to 50 ft at the max. data rate). RS232 works for full-duplex communication, that means it can transmit and receive data at the same time.

The RS232 signals are represented by voltage levels with respect to a system common (power / logic) ground. The "idle" state (MARK) has the signal level negative with respect to common, and the "active" state (SPACE) has the signal level positive with respect to common. RS232 has numerous handshaking lines (primarily used with modems), and also specifies a communications protocol. The RS-232 interface presupposes a common ground between the DTE (Data Terminal Equipment, usually a computer or terminal) and DCE (Data Circuit-terminating Equipment, usually a modem). This is a reasonable assumption when a short cable connects the DTE to the DCE, but with longer lines and connections between devices that may be on different electrical busses with different grounds, this may not be true.

RS422

When communicating at high data rates, or over long distances in real world environments, single-ended methods are often inadequate. Differential data transmission (balanced differential signal) offers superior performance in most applications. Differential signals can help nullify the effects of ground shifts and induced noise signals that can appear as common mode voltages on a network. RS422 (differential) was designed for greater distances and higher Baud rates than RS232. RS422 is a "drop-in" replacement for most RS232 applications. It is full-duplex and capable of long distance communications. In its simplest form, a pair of converters from RS232 to RS422 (and back again) can be used to form an "RS232 extension cord." Data rates of up to 100K bits / second and distances up to 4000 ft. can be accommodated with RS422. RS422 is also specified for multi-drop (party-line) applications where only one driver is connected to, and transmits on, a "bus" of up to 10 receivers. While a multi-drop "type" application has many desirable advantages, RS422 devices cannot be used to construct a truly multi-point network. A true multi-point network consists of multiple drivers and receivers connected on a single bus, where any node can transmit or receive data.

RS423

RS423 is another single ended specification with enhanced operation over RS232, however, it has not been widely used in the industry. RS423 is an unbalanced serial interface for the transmission of digital data. The EIA describes RS423 as a DTE to DCE interface only containing the electrical characteristics. Its speeds are defined from 20 kbps (where RS232 stops) to 100 kbps. All signals are defined with A and B lines, where all the B lines are tied to a common ground. The RS-423 standard defines a serial interface between one transmitter and many receivers. The voltage levels are +3.6 to +6 volts to represent a binary 0 and -3.6 to -6 volts to represent a binary 1. The voltage levels are defined relative to an earth ground potential assumed to be zero volts. Consequently a difference in ground voltage levels will result in the common mode voltage problem that will confuse the data values.

RS485

The RS485 and RS422 standards have much in common, and are often confused for that reason. RS485, which specifies bi-directional, half-duplex data transmission, is the only EIA standard that allows multiple receivers and drivers in "bus" configurations. RS422, on the other hand, specifies a single, unidirectional driver with multiple receivers. RS485 parts are backward-compatible and interchangeable with their RS422 counterparts, but RS422 drivers should not be used in an RS-485 system because they cannot relinquish control of the bus. RS485 meets the requirements for a truly multi-point communications network, and the standard specifies up to 32 drivers and 32 receivers on a single (2-wire) bus. With the introduction of "automatic" repeaters and high-impedance drivers / receivers this "limitation" can be extended to hundreds (or even thousands) of nodes on a network. RS485 extends the common mode range for both drivers and receivers in the "tri-state" mode and with power off. Also, RS485 drivers are able to withstand "data collisions" (bus contention) problems and bus fault conditions. An RS-485 network can be connected in a 2 or 4 wire mode. Maximum cable length can be as much as 4000 feet because of the differential voltage transmission system used. The typical use for RS485 is a single PC connected to several addressable devices that share the same cable. RS232 may be converted to RS485 with a simple interface converter. In a "two-wire" network the transmitter and receiver of each device are connected to a twisted pair.

SPECIFICATIONS	**RS232**		**RS423**	**RS422**	RS485
Mode of Operation	SINGLE -ENDED		SINGLE -ENDED	DIFFERENTIAL	DIFFERENTIAL
Total Number of Drivers and Receivers on One Line (One driver active at a time for RS485 networks)	1 DRIVER 1 RECVR		1 DRIVER 10 RECVR	1 DRIVER 10 RECVR	32 DRIVER 32 RECVR
Maximum Cable Length	50 FT.		4000 FT.	4000 FT.	4000 FT.
Maximum Data Rate (40ft. - 4000ft. for RS422/RS485)	20kb/s		100kb/s	10Mb/s-100Kb/s	10Mb/s-100Kb/s
Maximum Driver Output Voltage	+/-25V		+/-6V	-0.25V to +6V	-7V to +12V
Driver Output Signal Level (Loaded Min.)	**Loaded**	+/-5V to +/-15V	+/-3.6V	+/-2.0V	+/-1.5V
Driver Output Signal Level (Unloaded Max)	**Unloaded**	+/-25V	+/-6V	+/-6V	+/-6V
Driver Load Impedance (Ohms)	3k to 7k		>=450	100	54
Max. Driver Current in High Z State	**Power On**	N/A	N/A	N/A	+/-100uA
Max. Driver Current in High Z State	**Power Off**	+/-6mA @ +/-2v	+/-100uA	+/-100uA	+/-100uA
Slew Rate (Max.)	30V/uS		Adjustable	N/A	N/A
Receiver Input Voltage Range	+/-15V		+/-12V	-10V to +10V	-7V to +12V
Receiver Input Sensitivity	+/-3V		+/-200mV	+/-200mV	+/-200mV
Receiver Input Resistance (Ohms), (1 Standard Load for RS485)	3k to 7k		4k min.	4k min.	>=12k

Table 5 Specification of RS232, RS422, RS423 and RS485 [16]

"Four-wire" networks have one master port with the transmitter connected to each of the "slave" receivers on one twisted pair. The "slave" transmitters are all connected to the "master" receiver on a second twisted pair. In either configuration, devices are addressable, allowing each node to be communicated to independently. RS485 operates

in a half duplex manner. That means only one device can transmit at a time while all other half duplex devices receive. Devices operate as transceivers, but not simultaneous transmit and receive. It is widely used data acquisition world.
The following is a specifications comparison table developed by Ron Smith.

3 Camera Control Software and its Graphical User Interface

Because the camera is a very important sensing device in the tracking system, its control was the fundamental task. The camera can be controlled in two ways. The first is by using the specific controller from Panasonic. The second is with the computer through the communication port. Since the communication port of the camera is a RS485 port, we had to connect an RS232-to-RS485 converter from the COM1 port of the computer to the camera. The software is to be implemented in Visual C++. The main question is to fully control the camera with the computer instead of the manual controller. If the mouse or keyboard sends an event commands, the camera should perform the function accordingly.

3.1 Basic Communication Configuration of WV-CS854A Camera

WV-CSR cameras has two blocks, the Camera Pan/Tilt Block and the I/F Block. The I/F

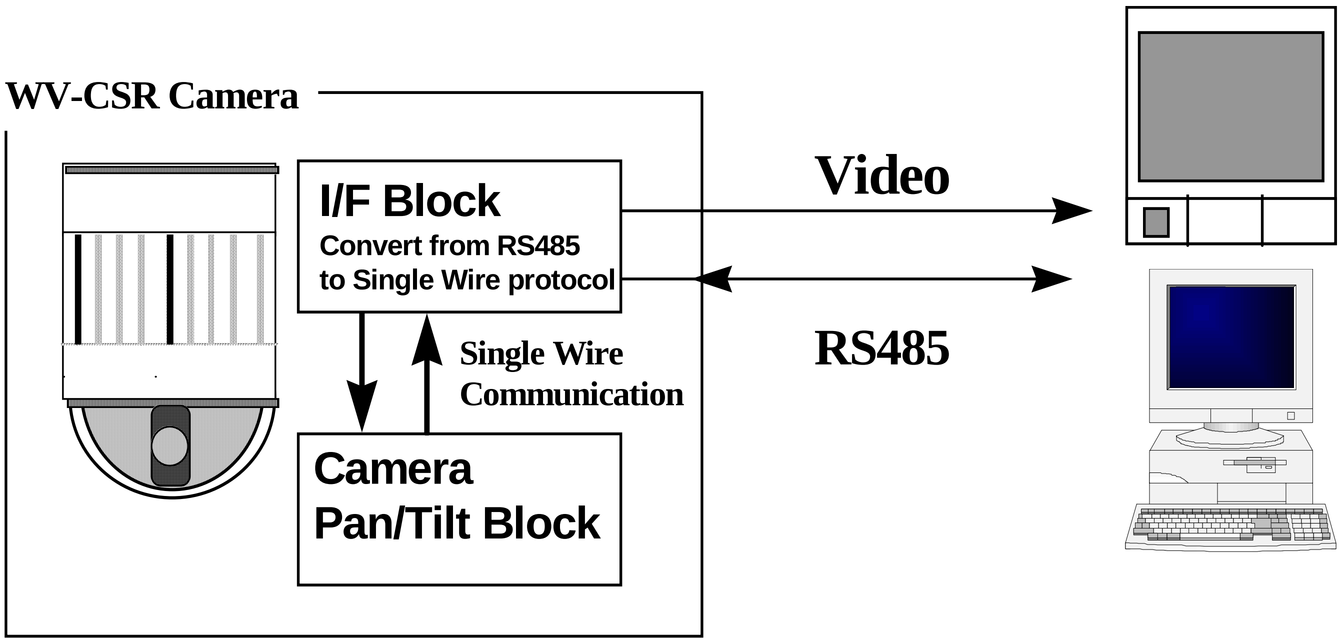


Figure8. Basic communication configuration of camera[13]

block converts commands from RS485 to the Panasonic single wire protocol, and then sends them to the Pan/Tilt block. The I/F block sends one command in a vertical blanking period. The communication between the I/F block and the Pan/tilt block is bidirectional which can send and receive data in a vertical blanking period.

The I/F block has a command buffer to store multiple commands from PC. Buffer capacity is about 1 Kbytes. When commands are sent to the I/F block, they are stored in the buffer, and then successively transferred to the Pan/Tilt block at the rate of one command in a vertical blanking period. If many commands are sent from PC, the response becomes slow. During the command transfer between the I/F block and the Pan/Tilt block, the I/F block can communicate to PC.

When the I/F block received a command from PC successfully, it sends back an ACK command to PC. When the Pan/Tilt Block received a command and done it successfully, it sends back an answer command to PC via the I/F block. When the buffer is full, I/F block cannot receive a data from PC until a stored command is completed. The buffer can be cleared by the buffer clear command.

There are two types protocol commands, one is single command, and the other is multiple command. The format of the command is as following:

Single command: STXGC7: xxxxxxxETX

Multiple Commands: STXGCF:xxxxxxx:xxxxxxxETX

Single command got single answer, and multiple commands got multiple answer. The communication procedure of single and multiple commands are shown as figure9 and figure10.

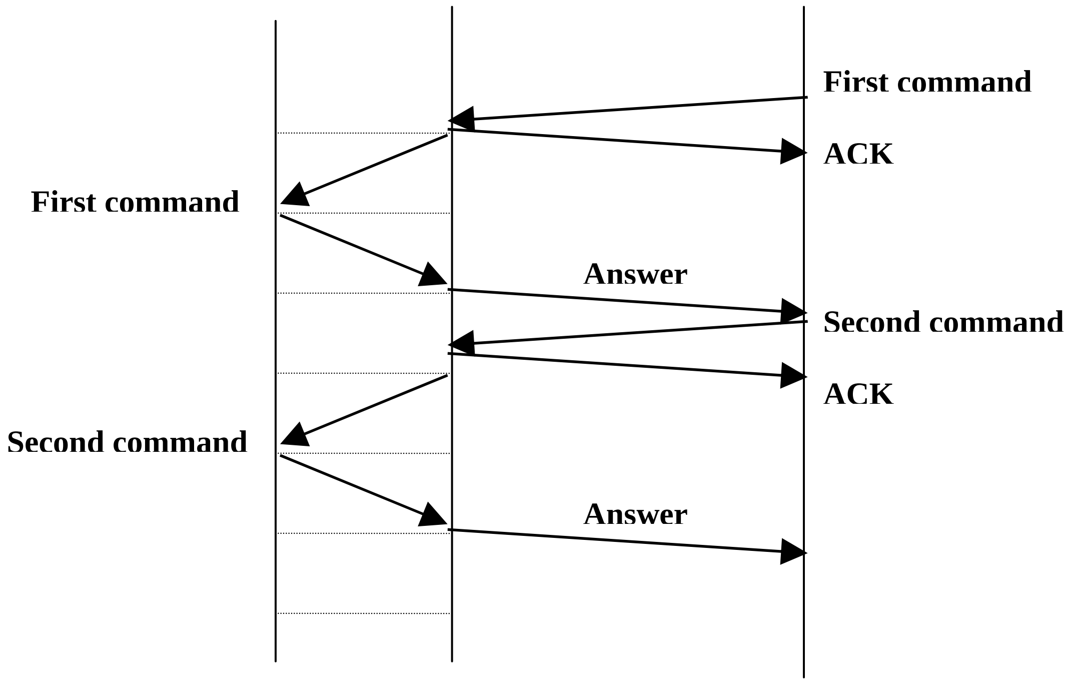


Figure9. Communication procedure for single command

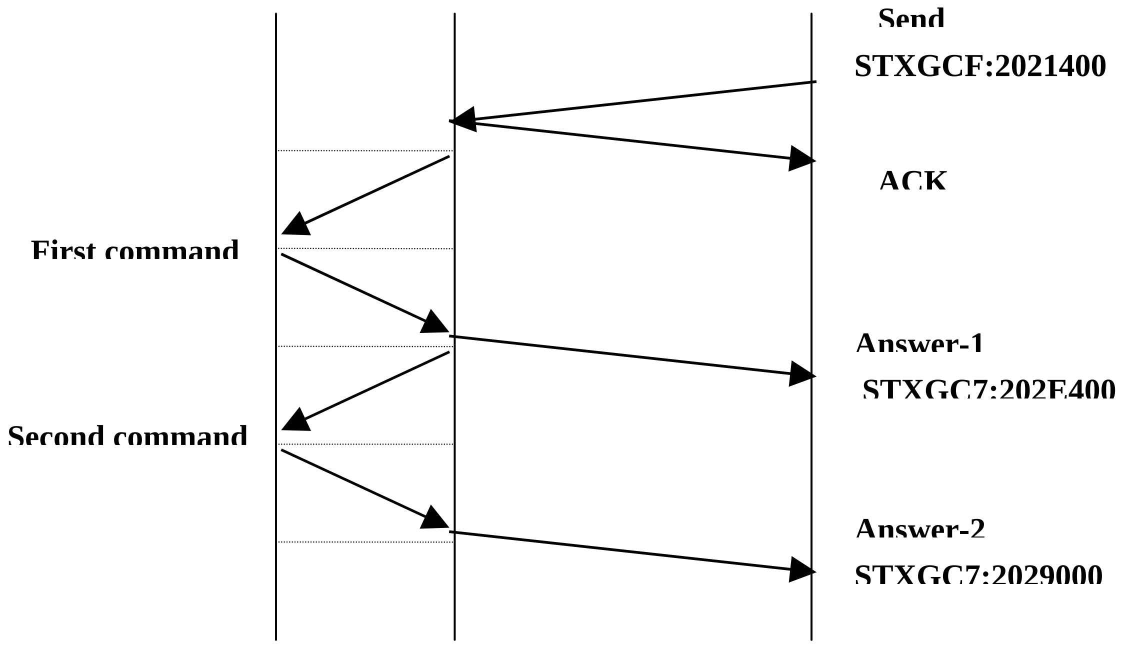


Figure10. Communication procedure of multiple commands

3.2 *Camera Control Software*

This camera control software was written with Visual C++ using the Panasonic camera command protocol. The main idea is to realize the camera function by sending the protocol command to the camera. The commands are sent to camera through serial port (RS232) of the computer. Since the camera is RS485 interfaced, one RS232-to-RS485 converter is connected to the serial port. Its function is to convert RS232 signal to RS485 signal. The camera I/F block receives the command and transmits it to Pan/Tilt block. The Pan/Tilt block will execute the command.

This CS-WV854A camera supports two different protocols. One is Panasonic conventional protocol. The other one is Panasonic new camera protocol. The command structure is the same for both protocols. The main difference is that the conventional protocol can only control the moving direction without accurate camera position, while the new camera protocol provides a set of commands to control the coordinate position of Camera pan, tilt, zoom and focus, but the disadvantage is that when camera moves from one position to another, it has to move along one direction (pan or tilt), then another direction (tilt or pan), the camera will not move along the diagonal direction. For example, in the conventional protocol, the command for pan/tilt control is as following: "[STX][G][C][7][:][2][0][2][1][3][M][N][ETX]" where "M" stands for camera motor speed and "N" stands for camera moving direction. Using this command the camera can move along eight direction including right, left, up, down, right-up, left-up, right-down, left-down. With different combinations of panning and tilting speed, the camera can move arbitrary direction, but the accurate camera position such as pan angle 30 degree and tilt angle 45 degree cannot be controlled. In the new command protocol, the accurate camera coordinate position is given in the command. For the same moving purpose, we need to send two commands, one for pan angle, the other for tilt angle, e.g. Send[Stx][G][C][N][:][2][0][2][1][4][C][0][:][2][0][2][2][*a][*b][8][:][2][0][2][2][*c][*d][1][Etx], where [*a][*b][*c][*d]=Pan angle (Pan angle < 360 degree), and then Send [Stx][G][C][N][:][2][0][2][1][4][C][1][:][2][0][2][2][*e][*f][8][:][2][0][2][2][*g][*h][1][

Etx], where [*e][*f][*g][*h]=Tilt Angle (Tilt angle < 180 degree)[17]. For our application, since we need to deal with the camera hand-over, the accurate position of the camera is very important parameter for our system. We compile both protocols in our software, depends on the moving purpose, we can choose which protocol to use between the protocols.

The software was implemented in Visual C++, and consists of several class files including CControlDlg.cpp, CommandQueue.cpp, CameraCommand.cpp, and Camera.cpp.

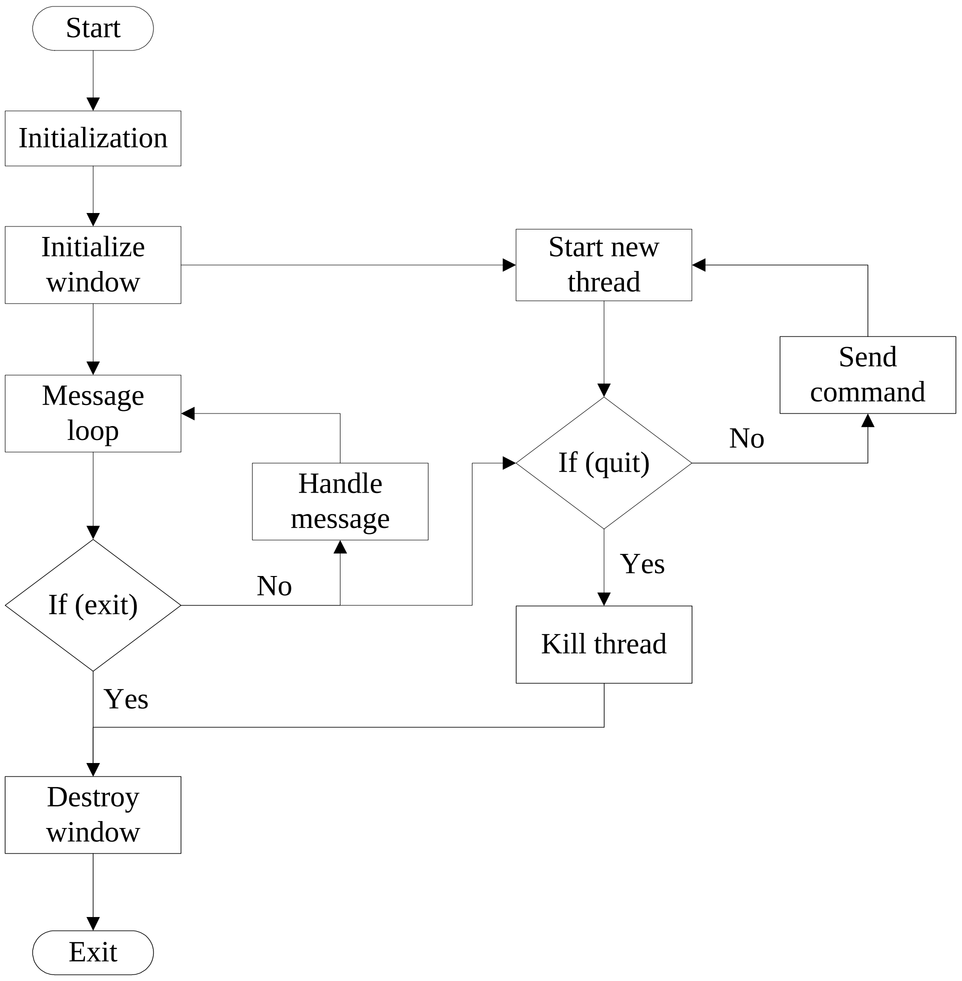
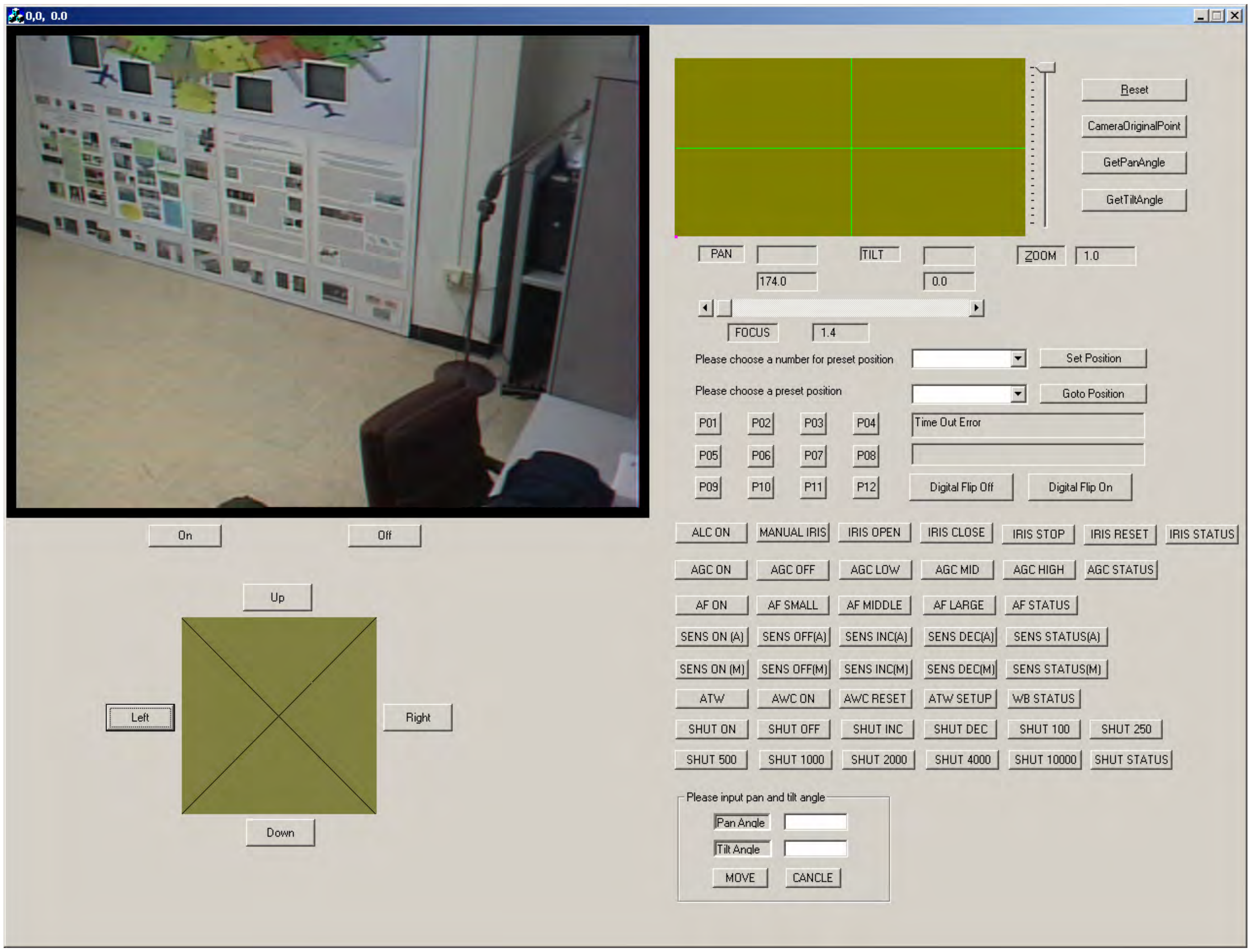


Figure 11 Flowchart of the software

Figure11 shows the flowchart of the software. CControlDlg.cpp is a dialog-based C++ file. Its function is to initialize all variables and windows, and also contains all the window messages and command functions. After initialization, a new thread is created and executed in CommandQueue.cpp. This thread is always running and waiting for windows message. The sending command and read feedback function is implemented in this class. This class sends command to camera and read feedback from the camera, and check the feedback signal with the correct answer signal, when the feedback is the same with the answer, it means the command has been executed successfully, the feedback will be displayed in the edit box in GUI, otherwise, a timeout error will be reported. IF the software is terminated, a message will be sent to kill the threads and destroy the windows, and then exit the program. All the camera control commands and their correct answers are stored in Camera.cpp. In this class, camera commands are implemented into functions, if one function is needed; a pointer is used to recall that function in main program. In CameraCommand.cpp, we changed the command format to the one that can be accepted by camera including symbols such as “STX”, “ETX”, camera ID, and command parameters.

This software contains two main threads. The advantage of multiple threads is in sharing CPU time. In our application, it’s mainly based on real-time, by using multiple threads, we can send more commands to camera while CPU is processing last command, we can also grab live image while last image is under processing. This can avoid using unnecessary loops and sleep function to wait on one processing job.

In this software, we implement basic functions of the PTZ camera such as panning, tilting, zooming and focusing. We also added more functions to the software to control the camera such as Automatic Light Control (ALC), Automatic Gain Control (AGC), Shutter control (SC), White Balance Control (WBC), Automatic Focus Control (AFC), and preset position, etc. We also implemented a function called ReadAnswer to get feedback from camera. Using the ReadAnswer function, we can get the exact position of the camera, current zooming ratio, current shutter speed, etc. We can also get some feedback about the current status of the camera such as ALC, AGC, AFC, and WBC. We can also determine whether these functions are controlled automatically or manually. We also implemented a function that can input live image sequences into the user interface software. By using this convenient setup, a human operator can control the camera moving direction to be aligned with the moving direction of the object. Figure12 shows the interface of the GUI.



PAN 174.0

TILT 0.0

ZOOM 1.0

FOCUS 1.4

Please choose a number for preset position

Please choose a preset position

Time Out Error

Please input pan and tilt angle

Pan Angle

Tilt Angle

Figure 12. Control Software GUI

There are three methods to control the camera position. The first is through a 360x180 workspace in the interface. This workspace provides a coordinate position control of the camera. Several methods were tried to control the mouse event. Results showed that clicking the mouse is easier to implement than dragging the mouse, and the result when moving by clicking the mouse is better than the dragging the mouse. One reason is that when dragging the mouse, too many commands are sent to the I/F block, this will cause a delay in camera movement. By double clicking the mouse, the camera can move to the angle wanted. The second method is using the edit box. You can input the angle value of panning and tilting. Using this method, the accuracy of the moving angle can be up to 0.1 degree. The third is another workspace that acts as a joystick. If we double click mouse in this area, the camera will move along the direction we give. But we cannot control the exactly position of the camera. This method is used for accurate position is not important such as just following a person. We also set up some pre-set position for the camera so that the camera can move to an area of interest quickly.

4 System Integration and Performance Evaluation

The entire system with a single camera was setup this semester. The hardware included the camera, RS232-RS485 converter, wireless transmitter and receiver, computer, frame grabber, null modem module and cables. To get a good view, we installed our camera on the ceiling. Since it is not always easy to install camera on the ceiling, since some places have a high ceiling (such as the airport), we design a camera mounting system to support the camera at any location to get the desired view.

4.1 Camera Mounting System

To make this system to an all-in-one and movable system, we designed a camera mounting system, which can provide a working space for the whole system. This camera mounting system is tripod-based system on a platform with four wheels. The platform provides a space to hold the battery for power. Another small platform on the top of the tripod will hold the camera and wireless transmitter and receiver. Some basic requirements of this mounting system are as following:

- Height should be about 4 meters so that a people's face will not be easily blocked.
- Must be very stable. Camera moving should not cause the system to shake.
- Must be foldable for easy installing and carrying.
- The price for the system should be reasonable.

For the base section, there are several choices to implement including tripod-based, single-pole based and tower based. Figure 13, 14, and 15 show these approaches. For the tripod-based system, it is very difficult to find good and heavy-duty tripod within a lower price range. It is very easy to cause camera to shake. For the single-pole system, it is not stable enough, and it needs a large basement to support a 4 meters high pole. On the contrary, the tower-based system is very easy to implement, and the cost for material is not high, and it is heavy-duty, it can supply more stability for the system, with tower, the system can easily extend to higher height.

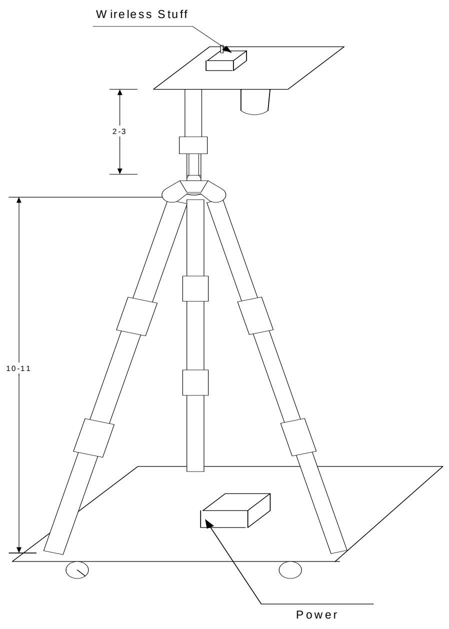


Figure13 Tripod-based system

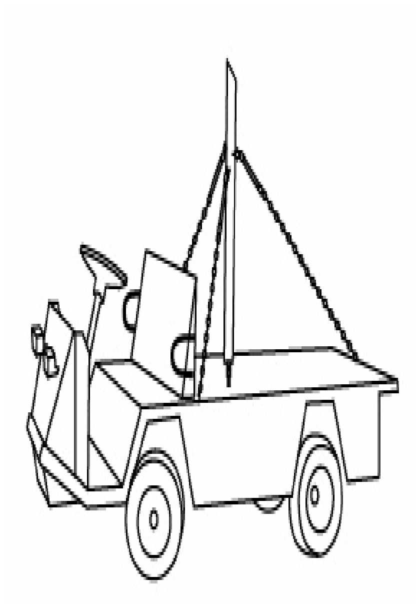


Figure14 Single-pole system

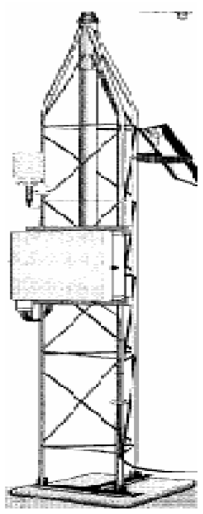


Figure15 Tower-based system

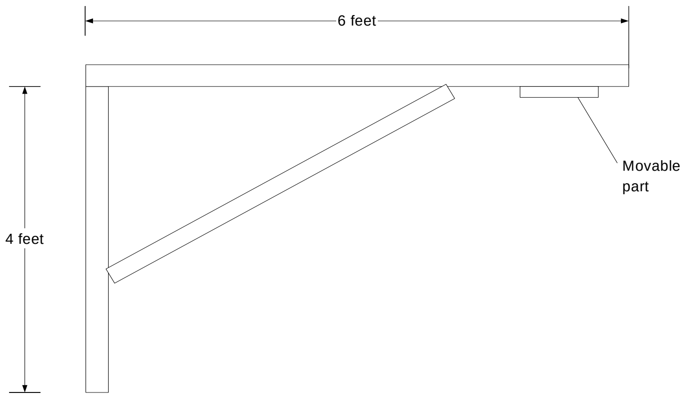


Figure16 Camera support bar

Figure16 shows a camera support bar that is on the top of the camera mounting system. Some requirements of the support bar are as following:

- Has a movable bar that can hold for camera and change camera position
- Should be made of light weight material
- The arm is long enough that people can move under the camera.
- The material should be strong enough for camera and other necessary equipment.

We made one with wood, and are working on other better material.

4.2 Installation Manual

There are two version of system. One is wireless version. In this version, we connect the wireless transmitter and receiver to computer and camera. The other one is the wired version. In this version, we use cable to connect all the components of the system. The basic procedure for both connection methods is the same. We will discuss this procedure step by step.

First, install Matrox Meteor-II frame grabber for computer. Remove the cover of the computer; insert frame grabber to an empty PCI slot.

Secondly, connect video source. Use BNC cable to connect the video output on the camera and the video input of the frame grabber. If using wireless version, connect video transmitter to camera and wireless video receiver to the frame grabber.

Thirdly, camera setting up including setting the camera ID, RS485 setup, remember set RS485 communication to 2-wire connection. Details please refer to camera manual.

Next, communication setup. This part is really important. On camera RS485 port, there are 5 pins, which support both 2-wire and 4-wire RS485 communication. In our system, we use 2-wire connection. So at first, we connect all TB and RB, TA and RA together to form a three-wire connection including A, B, and ground. Then we connect these three wires to the RS485 converter, the order should be A to A, B to B, and ground to ground. Finally, we connect the converter to computer. If it is used in wireless version, a wireless transceiver will be connected to serial port of computer, another transceiver should be connected with the RS485 converter through a null-modem module, the reason is both transceiver and converter are DCE (Data Communication Equipment).

Finally, check the connection again. If everything is ok, just turn on all the power, and launch the software, you can work with this system.

4.3 System Performance Evaluation

We tested our system with both wireless and wired connections. Testing included video and control data communication.

For wireless communication, we use a setup system as shown in Figure17. In this setup, the whole system is built on a tripod base. The camera is about 10 feet high. We made the test on 4th floor of Ferris Hall. The results show that the effect communication distance for video is about 50 feet, and for control data is about 70 feet. There exist some problem

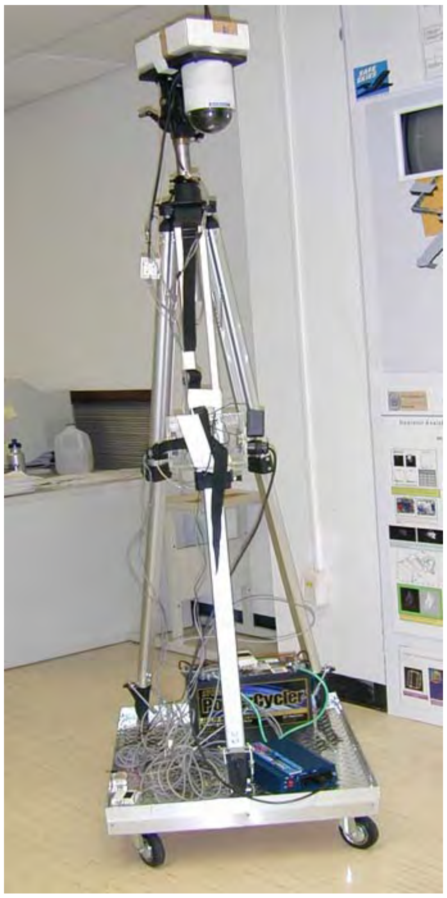


Figure17. Wireless test system

during the test. Image quality is not stable. Objects between transmitter and receiver will affect the image quality. The reason for this is that firstly the current wireless transmitter and receiver is not powerful enough. Secondly, the frame grabber is not work well with wireless communication. It will cause the image to stop or completely lost the image. Finally, bad connection inside the transmitter and receiver and cable may be a reason for poor image quality. For control data test, the software can send command to camera, but cannot receive the feedback from the camera. The first possible reason is that the wireless transceiver. Sending too many commands may cause the transceiver encode the wrong command. Since the transceiver can hold 64 byte command, if the command is send too fast, the last command will be cut in the command buffer. The second reason may be the bugs in the software. Since we compare the feedback with the correct answer. If camera feedback does not come back through the transceiver, it will cause the software a dead loop. If this is true, we need to modify the software.

For the wired system, we tested the system with various length cables. We used two ways to connect the cable, one is to directly connect RS485 converter to the computer, and the other is connect the RS485 converter to the computer through a 6 foot RS232 cable. We tested with are 10’, 20’, 30’, 100’, 200’, and 400’ RS485 cable. The result shows that for cable length less than 200 feet, the whole system works well. There is some delay as cable become longer. The longer the cable is, the higher the delay is. For 400 feet cable, the delay is more than 2 seconds; this cause the system cannot get correct feedback from the camera. One solution is to use a shorter cable for communication; the other solution is to use a repeater in the middle of the cable. For video, the cable length does not affect the image quality for cable length less than 400 feet.

5. Experiment Results

Various experiments were conducted with our PTZ camera system. The purpose of these experiments was to apply this system with our tracking algorithm. To simplify the experiment, we only use wired communication for these experiments. For these experiments, the PTZ camera was set on the ceiling about 9 feet high, the moving range of the object was about 13foot by 10foot rectangle in our office.

5.1 Stationary Camera Controlled PTZ Camera System

The first experiment was to use a stationary camera and the PTZ system. The function of the stationary camera was to capture the object, detect the biggest moving region in the images, and provide object-moving information such as position and moving direction of movement for the PTZ camera. The PTZ camera gets information from the stationary camera. By receiving the moving position command, the PTZ camera changes to the preset-position, and track the object to get the right view of the object.

For this purpose, we determined 12 preset positions in the moving region. We choose 12 points in the region, the distance between two position is set to equal in the x and y direction, thus the cover range for every position is about 3 feet x 3 feet. Figure 18 shows all the preset positions. In the algorithm, we use the position of the object head as the reference. For every preset position, we change the pan and tilt zoom angle of the lens and the zoom ratio to always keep the object in the middle of the view and the top of the object at the same height.

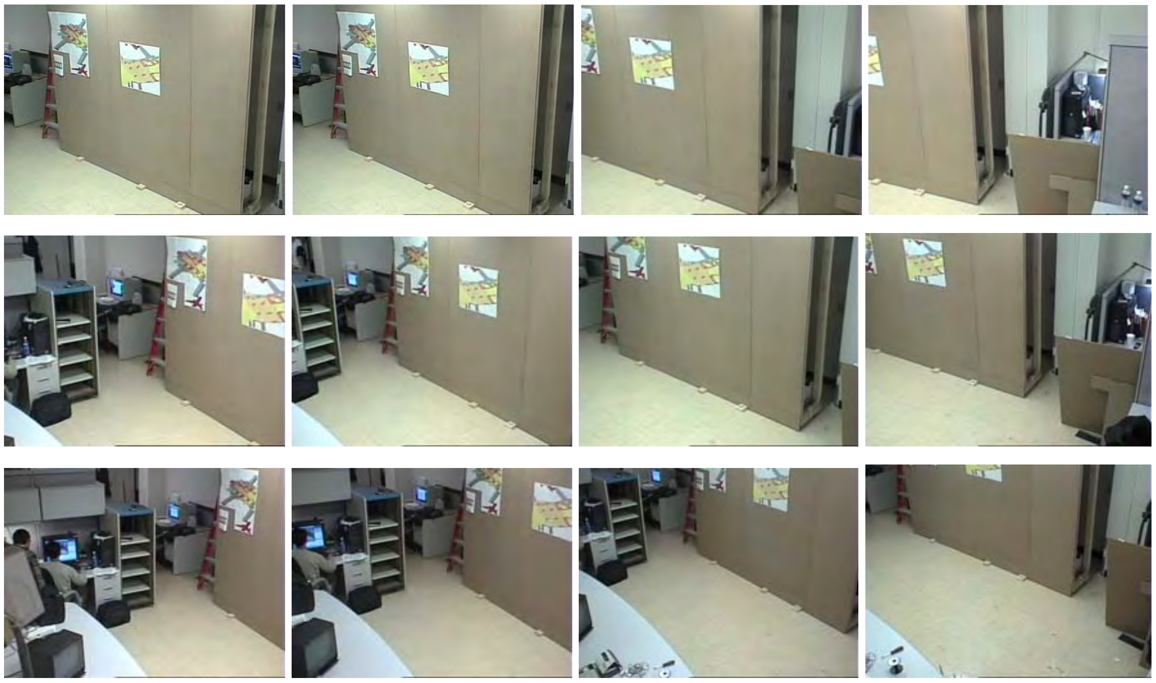
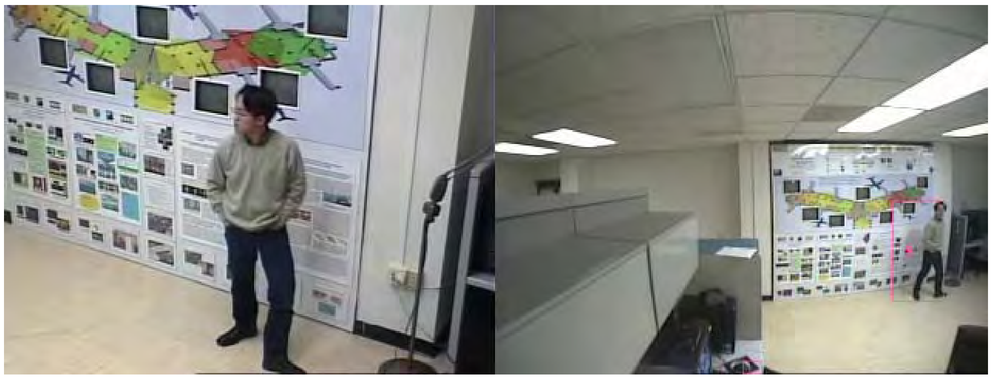
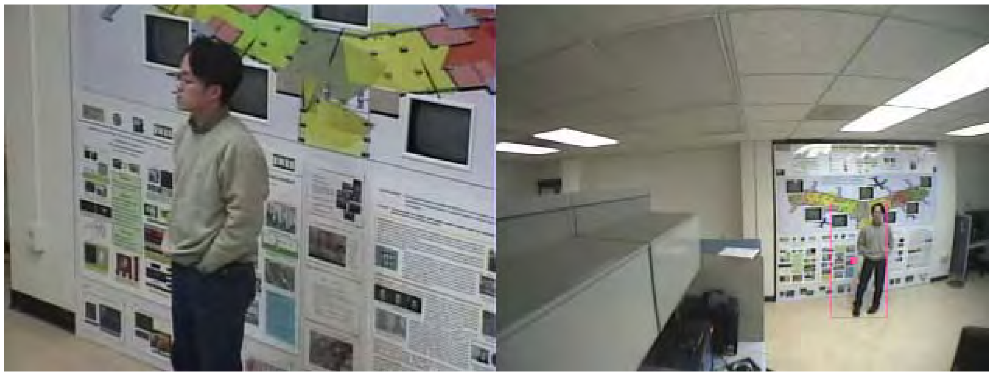


Figure 18. PTZ Camera Preset Position

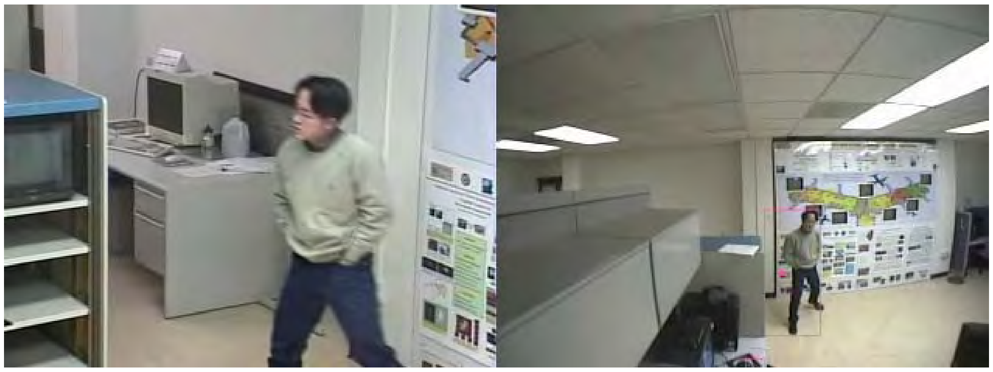
Some frames of the experimental results are shown in Figure 19 (a, b, c, d). In theses frame, the right images are captured by stationary camera. The rectangle indicates the moving region. The left images were grabbed by PTZ camera. The results show that control of the PTZ camera can be achieved by position parameters. For more accurate control, we need to provide more position information. This experiment will be applied in a direction detection project, which will be used in airport to detect the object in the wrong direction of the exit lane. The difference is the PTZ camera will change its view according to the current position instead of a preset position.



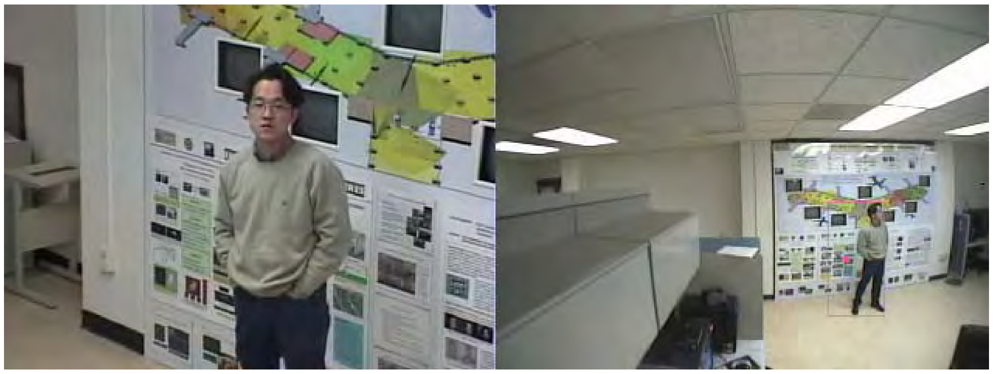
(a)



(b)



(c)



(d)

Figure 19. Sample Frames of Stationary Camera Control Tracking

5.2 Color Tracking with PTZ Camera

This experiment was implemented with the PTZ camera. The purpose of this experiment was to grab images while the camera is rotating. The Multi-rate Gaussian distribution for each color channel was used to track color region that is initiated by user. Once color region is defined, we compute the difference between frames. If the difference is smaller than a threshold, this is considered it the same color region. Based upon the moving direction of the color region, we send moving command such pan-right, tilt-up, and combination of pan and tilt to control the moving direction of the PTZ camera. Figure 20 shows some frames of the experimental results. In theses frames, the larger image is the grabbed image, and the cross in the smaller image marks out the center of the color region. This algorithm is concentrated on tracking the center of the color region.

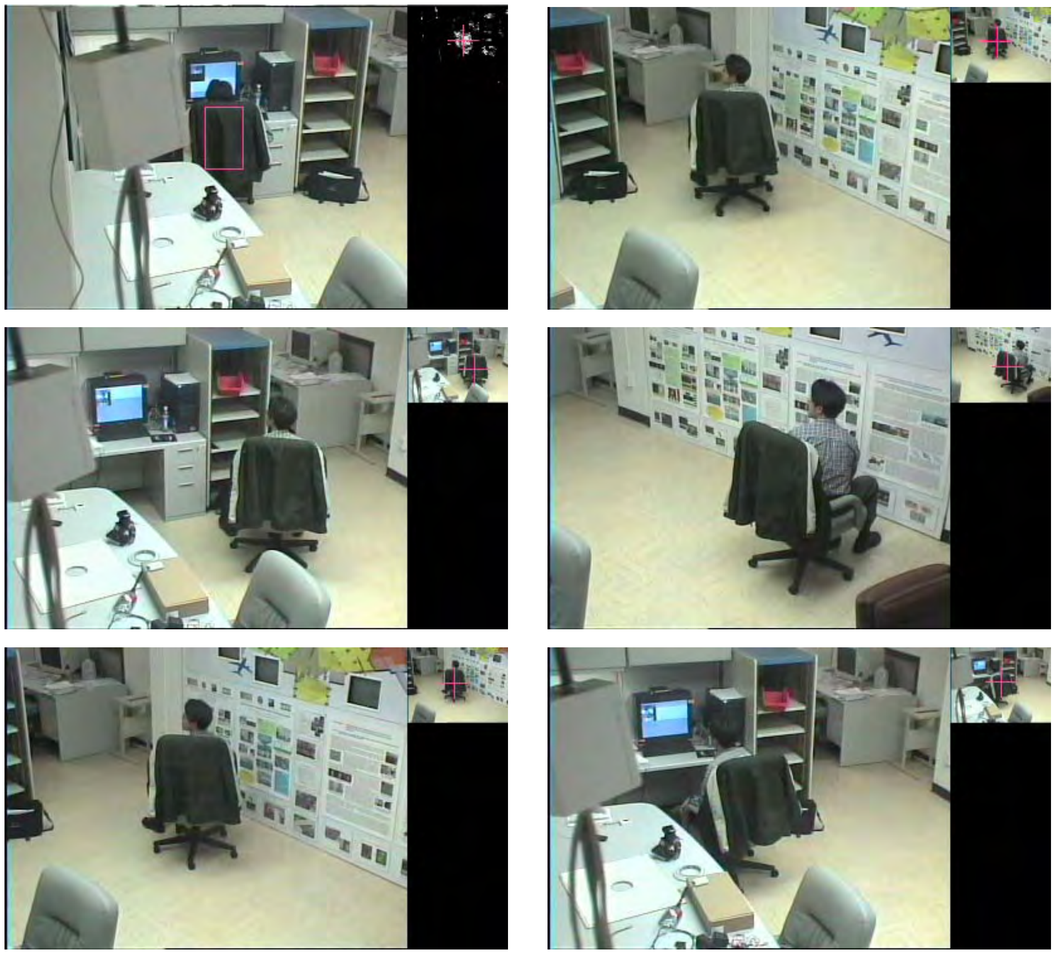


Figure 20. Image Sequence of Color Tracking

6. Conclusion and Future Plans

A hardware implementation of a wireless real-time video tracking system is proposed in this paper. Its architecture and module definitions are given. The complete system consists of three PTZ cameras, a wireless video transmitter and receiver, frame grabber, computer, and wireless transceiver for the control data. The hardware specifications are discussed. This system can be controlled either by a controller or by a remote computer. The interface and control of this hardware system is implemented. Control of the camera is the main task of the controlling system. The software is implemented in Visual C++ and can control the function of the camera such as panning, tilting zooming and focusing; it can also control ALC, AGC, shutter speed, white balance, Sensitivity, and etc. A system with single camera was setup and tested. The result shows that the system work well with wired connection. Cable length will affect the performance of the system. For wireless communication, some problems exist. These problems are related to the performance of the wireless transmitter and receiver. We truly believe if we use better wireless equipment, these problems can be solved. A camera mounting system is designed for the system. With this mounting system, the whole system can be easily move around and is stable in various environments.

In the future, a multiple camera system should be setup as soon as possible. Some necessary test should be completed with the multiple camera system including hardware and software. The whole system should be tested with video tracking algorithms and be ready for the final demonstration in the airport.

The GUI for the control software needs to be modified to make it more users friendly and beautiful. Some functions need to be improved after some test. The sending and read feedback function should be re-implement for wireless communication. For future use, we should consider various communication interfaces such as the parallel port, USB port, and fire-ware port. As an automated goal, the software should work for multiple cameras and multiple communication interfaces.

The digital system is a trend for future video surveillance. For better image quality and optimum processing speed, this system will upgrade to a digital system. We have completed a partial survey on digital equipment, as soon as we can solve the existing problem in current system, we will also work on digital system.

References

[1] Koller, D., Klinker, G., Rose, E., Breen, D., Whitaker, R., and Tuceryan, M. “Real-time Vision-based Camera Tracking for Augmented Reality Applications”, Proceedings of the ACM Symposium on Virtual Reality Software and Technology (VRST--97), 1997, Pages 87--94.

[2] Corke, P.I.; Hutchinson, S.A. “Real-time vision, tracking and control”, Robotics and Automation, 2000. Proceedings. ICRA '00. IEEE International Conference, Volume: 1 , 2000 Page(s): 622 –629.

[3] Davis, J.W.; Bobick, A.F. “The representation and recognition of human movement using temporal templates”, Computer Vision and Pattern Recognition, 1997. Proceedings., 1997 IEEE Computer Society Conference, 1997, Page(s): 928 –934

[4] Haritaoglu I.; Harwood D.; Larry S.D., “W4: Real-time surveillance of people and their activities”, IEEE Transaction on Pattern Analysis and Machine Intelligence, Vol. 22, No. 8, August, 2000, Page(s): 809 – 830.

[5] Xiaodong Liu; Guangda Su, “A new network-based intelligent surveillance system”, Signal Processing Proceedings, 2000. WCCC-ICSP 2000. 5th International Conference, Volume: 2 , 2000, Page(s): 1187 –1192.

[6] Collins R.; Lipton A.; Kanade T.; Fujiyoshi H.; Duggins D.; Tsin Y.; Tolliver D.; Enomoto N.; and Hasegawa O.; “ A system for video surveillance and monitoring”, technical report CMU-RI-TR-00-12, Robotics Institute, Carnegie Mellon University, May, 2000.

[7] Lipton A., Fujiyoshi H., Patil R., “Moving target classification and tracking from real-time video”, Proceedings, Fourth IEEE Workshop on Applications of Computer Vision, WACV, 98, October 19—21, 1998, Princeton, New Jersey. Page(s): 8-14

[8] Wren, C.R.; Azarbayejani, A.; Darrell, T.; Pentland, A.P. “Pfinder: real-time tracking of the human body”, Pattern Analysis and Machine Intelligence, IEEE Transactions, Volume: 19 Issue: 7 , July 1997 Page(s): 780 -785

[9] Rehg, J.M.; Loughlin, M.; Waters, K. “Vision for a smart kiosk”, Computer Vision and Pattern Recognition, 1997. Proceedings., 1997 IEEE Computer Society Conference, 1997 Page(s): 690 -696

[10] Krumm, J.; Harris, S.; Meyers, B.; Brumitt, B.; Hale, M.; Shafer, S. “Multi-camera multi-person tracking for EasyLiving”, Visual Surveillance, 2000. Proceedings. Third IEEE International Workshop, 2000 Page(s): 3 -10

[11] Sherrah, J.; Gong, S. “VIGOUR: A system for tracking and recognition of multiple people and their activities”, Pattern Recognition, 2000. Proceedings. 15th International Conference, Volume: 1 , 2000 Page(s): 179 –182.

[12] Yachi, K.; Wada, T.; Matsuyama, T. “Human head tracking using adaptive appearance models with a fixed-viewpoint pan-tilt-zoom camera”, Automatic Face and Gesture Recognition, 2000. Proceedings. Fourth IEEE International Conference, 2000 Page(s): 150 -155

[13] Panasonic Company, “protocol information”, Panasonic CCVE Products Document Number 010, Nov.27.1997

[14] Matrox Imaging Tutorial, “camera Interface Guide”, Page(s) 3-15

[15] WWW.matrox.com

[16] http://www.rs485.com/

[17] Panasonic Company, “Protocol information for WV-CS850”, version 2.0, 2000

Appendix

(Camera.cpp, CameraCommand.cpp, CommandQueue.cpp, CcontrolDlg.cpp and serial.cpp)

// **Camera.cpp**: implementation of the CCamera class.

```
#include "stdafx.h"
#include "ControlCommand.h"
#include "Camera.h"
#ifdef _DEBUG
#undef THIS_FILE
static char THIS_FILE[]=__FILE__;
#define new DEBUG_NEW
#endif
//////////////////////////////////////////////////////////////////////////////
//
// Various camera function commands and their answer.
//
//////////////////////////////////////////////////////////////////////////////
CCameraCommand
CCamera::s_Zoom("[GCN:20214B0:2022**8:2022**1]","[GC7:202E4B0][GC7:2029**
8][GC7:2029**1]");
CCameraCommand
CCamera::s_Focus("[GCN:20214B1:2022**8:2022**1]","[GC7:202E4B1][GC7:2029**
8][GC7:2029**1]");
CCameraCommand
CCamera::s_Pan("[GCN:20214C0:2022**8:2022**1]","[GC7:202E4C0][GC7:2029**8]
[GC7:2029**1]");
CCameraCommand
CCamera::s_Tilt("[GCN:20214C1:2022**8:2022**1]","[GC7:202E4C1][GC7:2029**8]
[GC7:2029**1]");
CCameraCommand
CCamera::s_PosCall("[GCF:2021400:2022**0]","[GC7:202E400][GC7:2029**0]");
CCameraCommand
CCamera::s_GetZoom("[GCF:2021490:20204A0]","[GC7:20249**][GC7:2024A**]");
CCameraCommand
CCamera::s_GetFocus("[GCF:20204B0:20204C0]","[GC7:2024B**][GC7:2024C**]");
CCameraCommand
CCamera::s_GetPan("[GCF:20203A0:20203B0]","[GC7:2023A**][GC7:2023B**]");
CCameraCommand
CCamera::s_GetTilt("[GCF:20203C0:20203D0]","[GC7:2023C**][GC7:2023D**]");
CCameraCommand
CCamera::s_Reset("[GCF:2021400:2022000]","[GC7:002E400][GC7:2029000]");
```

```
CCameraCommand
CCamera::s_HomePosition("[GCF:2021400:20223F0]","[GC7:002E400][GC7:20293F0]
");
CCameraCommand
CCamera::s_SetPosition("[GCV:2021540:2022**0:2021542:2021543]","[GC7:202E540]
[GC7:2029**0][GC7:202E542][GC7:202E543]");
CCameraCommand
CCamera::s_GetPosition("[GCF:2021400:2022**0]","[GC7:202E400][GC7:2029**0]");
CCameraCommand CCamera::s_IRISManual("[GC7:0021034]","[GC7:002E034]");
CCameraCommand CCamera::s_ALCOn("[GC7:0021032]","[GC7:002E032]");
CCameraCommand CCamera::s_IRISOpen("[GC7:0021002]","[GC7:002E002]");
CCameraCommand CCamera::s_IRISClose("[GC7:0021003]","[GC7:002E003]");
CCameraCommand CCamera::s_IRISStop("[GC7:0021004]","[GC7:002E004]");
CCameraCommand CCamera::s_IRISReset("[GC7:0021005]","[GC7:002E005]");
CCameraCommand CCamera::s_AGCOn("[GC7:0021200]","[GC7:002E200]");
CCameraCommand CCamera::s_AGCOff("[GC7:0021201]","[GC7:002E201]");
CCameraCommand CCamera::s_AGCLow("[GC7:0021208]","[GC7:002E208]");
CCameraCommand CCamera::s_AGCMid("[GC7:0021209]","[GC7:002E209]");
CCameraCommand CCamera::s_AGCHigh("[GC7:002120A]","[GC7:002E20A]");
CCameraCommand CCamera::s_AFOn("[GC7:0021A06]","[GC7:002EA06]");
CCameraCommand CCamera::s_AFSmall("[GC7:0021A18]","[GC7:002EA18]");
CCameraCommand CCamera::s_AFMiddle("[GC7:0021A19]","[GC7:002EA19]");
CCameraCommand CCamera::s_AFLarge("[GC7:0021A1A]","[GC7:002EA1A]");
CCameraCommand CCamera::s_IRISStatus("[GC7:0020102]","[GC7:002102*]");
CCameraCommand CCamera::s_AGCStatus("[GC7:0020121]","[GC7:002121*]");
CCameraCommand CCamera::s_AFStatus("[GC7:00201A2]","[GC7:0021A2*]");
CCameraCommand CCamera::s_SensAutoOn("[GC7:0021120]","[GC7:002E120]");
CCameraCommand CCamera::s_SensAutoOff("[GC7:0021121]","[GC7:002E121]");
CCameraCommand CCamera::s_SensAutoInc("[GC7:0021122]","[GC7:002E122]");
CCameraCommand CCamera::s_SensAutoDec("[GC7:0021123]","[GC7:002E123]");
CCameraCommand CCamera::s_SensAutoStatus("[GC7:0020112]","[GC7:00211**]");
CCameraCommand CCamera::s_SensManualOn("[GC7:0020150]","[GC7:002E150]");
CCameraCommand CCamera::s_SensManualOff("[GC7:0020151]","[GC7:002E151]");
CCameraCommand CCamera::s_SensManualInc("[GC7:0020152]","[GC7:002E152]");
CCameraCommand CCamera::s_SensManualDec("[GC7:0020153]","[GC7:002E153]");
CCameraCommand
CCamera::s_SensManualStatus("[GC7:0020116]","[GC7:00211**]");
CCameraCommand CCamera::s_ATWOn("[GC7:0021310]","[GC7:002E310]");
CCameraCommand CCamera::s_AWCOn("[GC7:0021300]","[GC7:002E300]");
CCameraCommand CCamera::s_AWCReset("[GC7:0021305]","[GC7:002E305]");
CCameraCommand
CCamera::s_AWCSetup("[GCF:0021300:0021306]","[GC7:002E300][GC7:002E306]");
CCameraCommand CCamera::s_WBStatus("[GC7:0020130]","[GC7:002130*]");
CCameraCommand CCamera::s_ShutterOn("[GC7:0021100]","[GC7:002E100]");
CCameraCommand CCamera::s_ShutterOff("[GC7:0021101]","[GC7:002E101]");
CCameraCommand CCamera::s_ShutterInc("[GC7:0021102]","[GC7:002E102]");
CCameraCommand CCamera::s_ShutterDec("[GC7:0021103]","[GC7:002E103]");
CCameraCommand CCamera::s_Shutter100("[GC7:0021109]","[GC7:002E109]");
CCameraCommand CCamera::s_Shutter250("[GC7:002110C]","[GC7:002E10C]");
CCameraCommand CCamera::s_Shutter500("[GC7:002110D]","[GC7:002E10D]");
CCameraCommand CCamera::s_Shutter1000("[GC7:002110E]","[GC7:002E10E]");
CCameraCommand CCamera::s_Shutter2000("[GC7:002110F]","[GC7:002E10F]");
CCameraCommand CCamera::s_Shutter4000("[GC7:0021119]","[GC7:002E119]");
CCameraCommand CCamera::s_Shutter10000("[GC7:002111A]","[GC7:002E11A]");
CCameraCommand CCamera::s_ShutterStatus("[GC7:0020110]","[GC7:00211**]");
CCameraCommand CCamera::s_PanRightS("[GC7:202135C]","[GC7:202E35C]");
CCameraCommand CCamera::s_PanRightF("[GC7:202132C]","[GC7:202E32C]");
CCameraCommand CCamera::s_PanLeftS("[GC7:2021358]","[GC7:202E358]");
CCameraCommand CCamera::s_PanLeftF("[GC7:2021328]","[GC7:202E328]");
CCameraCommand CCamera::s_TiltUpS("[GC7:202135A]","[GC7:202E35A]");
CCameraCommand CCamera::s_TiltUpF("[GC7:202132A]","[GC7:202E32A]");
CCameraCommand CCamera::s_TiltDownS("[GC7:202135E]","[GC7:202E35E]");
CCameraCommand CCamera::s_TiltDownF("[GC7:202132E]","[GC7:202E32E]");
CCameraCommand CCamera::s_PanRSTiltUS("[GC7:202135B]","[GC7:202E35B]");
CCameraCommand CCamera::s_PanRSTiltUF("[GC7:202134B]","[GC7:202E34B]");
CCameraCommand CCamera::s_PanRFTiltUS("[GC7:202133B]","[GC7:202E33B]");
CCameraCommand CCamera::s_PanRFTiltUF("[GC7:202132B]","[GC7:202E32B]");
CCameraCommand CCamera::s_PanLSTiltUS("[GC7:2021359]","[GC7:202E359]");
CCameraCommand CCamera::s_PanLSTiltUF("[GC7:2021349]","[GC7:202E349]");
CCameraCommand CCamera::s_PanLFTiltUS("[GC7:2021339]","[GC7:202E339]");
CCameraCommand CCamera::s_PanLFTiltUF("[GC7:2021329]","[GC7:202E329]");
CCameraCommand CCamera::s_PanRSTiltDS("[GC7:202135D]","[GC7:202E35D]");
CCameraCommand CCamera::s_PanRSTiltDF("[GC7:202134D]","[GC7:202E34D]");
CCameraCommand CCamera::s_PanRFTiltDS("[GC7:202133D]","[GC7:202E33D]");
CCameraCommand CCamera::s_PanRFTiltDF("[GC7:202132D]","[GC7:202E32D]");
CCameraCommand CCamera::s_PanLSTiltDS("[GC7:202135F]","[GC7:202E35F]");
CCameraCommand CCamera::s_PanLSTiltDF("[GC7:202134F]","[GC7:202E34F]");
CCameraCommand CCamera::s_PanLFTiltDS("[GC7:202133F]","[GC7:202E33F]");
CCameraCommand CCamera::s_PanLFTiltDF("[GC7:202132F]","[GC7:202E32F]");
CCameraCommand CCamera::s_CameraStopSS("[GC7:2021354]","[GC7:202E354]");
CCameraCommand CCamera::s_CameraStopSF("[GC7:2021344]","[GC7:202E344]");
CCameraCommand CCamera::s_CameraStopFS("[GC7:2021334]","[GC7:202E334]");
CCameraCommand CCamera::s_CameraStopFF("[GC7:2021324]","[GC7:202E324]");
//////////////////////////////////////////////////////////////////////
// Construction/Destruction
//////////////////////////////////////////////////////////////////////
CCamera::CCamera()
:m_ID("")  // initialize m_ID
{
}
CCamera::~CCamera()
{
}
CCamera::CCamera(CCommandQueue *pCommandQueue, CString sCarmeraID)
:m_ID(sCarmeraID)
{
	m_pCommandQueue = pCommandQueue;
}
// Zoom function
int CCamera::Zoom(float fZoom)
{
	char buff[5];
	sprintf(buff, "%04d", (int)(fZoom)%10000);
	CControlCommand tempCommand(m_ID);		// get camera ID
	tempCommand.AddCameraCommand(s_Zoom, buff); // Get send command and 
parameters
	m_pCommandQueue->AddCommand(tempCommand);   // Send command to 
command array
	return 0;
}
//Camera move function including pan and tilt with coordinate position
void CCamera::MoveToAngle(float fX, float fY)
{
	char buff[5];
	CControlCommand tempCommand(m_ID);
	sprintf(buff, "%04d", (int)(fX*10)%10000);
	tempCommand.AddCameraCommand(s_Pan, buff);
	sprintf(buff, "%04d", (int)(fY*10)%10000);
	tempCommand.AddCameraCommand(s_Tilt, buff);
	m_pCommandQueue->AddCommand(tempCommand);
}
//Goto preset position
void CCamera::GotoPosition(int iPos)
{
	char buff[5];
	sprintf(buff, "%02d", iPos%100);
	CControlCommand tempCommand(m_ID);
	tempCommand.AddCameraCommand(s_PosCall, buff);
	m_pCommandQueue->AddCommand(tempCommand);
}

//FOcusing function with position
void CCamera::Focuse(float fDis)
{
	char buff[5];
	sprintf(buff, "%04d", (int)(fDis*10)%10000);
	CControlCommand tempCommand(m_ID);
	tempCommand.AddCameraCommand(s_Focus, buff);
	m_pCommandQueue->AddCommand(tempCommand);
}
//Manual IRIS function
void CCamera::IRISManual()
{
	CControlCommand tempCommand(m_ID);
	tempCommand.AddCameraCommand(s_IRISManual, "");
	m_pCommandQueue->AddCommand(tempCommand);
}
// Automatic light control function
void CCamera::ALCOn()
{
	CControlCommand tempCommand(m_ID);
	tempCommand.AddCameraCommand(s_ALCOn, "");
	m_pCommandQueue->AddCommand(tempCommand);
}
//Get pan angle function
void CCamera::GetPan()
{
	CControlCommand tempCommand(m_ID);
	tempCommand.AddCameraCommand(s_GetPan, "");
	m_pCommandQueue->AddCommand(tempCommand);
}
//Get tilt angle function
void CCamera::GetTilt()
{
	CControlCommand tempCommand(m_ID);
	tempCommand.AddCameraCommand(s_GetTilt, "");
	m_pCommandQueue->AddCommand(tempCommand);
}
//Goto preset home position1
void CCamera::Reset()
{
	CControlCommand tempCommand(m_ID);
	tempCommand.AddCameraCommand(s_Reset, "");
	m_pCommandQueue->AddCommand(tempCommand);
}
//Goto camera homeposition (0,0)
void CCamera::HomePosition()
{
	CControlCommand tempCommand(m_ID);
	tempCommand.AddCameraCommand(s_HomePosition, "");
	m_pCommandQueue->AddCommand(tempCommand);
}
//Manual IRIS open function, timeout 2.2 second unless get "stop" command
void CCamera::IRISOpen()
```

```
{
	CControlCommand tempCommand(m_ID);
	tempCommand.AddCameraCommand(s_IRISOpen, "");
	m_pCommandQueue->AddCommand(tempCommand);
}
//Manual IRIS close function, timeout 2.2 second unless get "stop" command
void CCamera::IRISClose()
{
	CControlCommand tempCommand(m_ID);
	tempCommand.AddCameraCommand(s_IRISClose, "");
	m_pCommandQueue->AddCommand(tempCommand);
}
//Manual IRIS stop function
void CCamera::IRISStop()
{
	CControlCommand tempCommand(m_ID);
	tempCommand.AddCameraCommand(s_IRISStop, "");
	m_pCommandQueue->AddCommand(tempCommand);
}
//Iris reset to original setting
void CCamera::IRISReset()
{
	CControlCommand tempCommand(m_ID);
	tempCommand.AddCameraCommand(s_IRISReset, "");
	m_pCommandQueue->AddCommand(tempCommand);
}
//Automatic gain control on function
void CCamera::AGCOn()
{
	CControlCommand tempCommand(m_ID);
	tempCommand.AddCameraCommand(s_AGCOn, "");
	m_pCommandQueue->AddCommand(tempCommand);
}
//Automatic gain control off function
void CCamera::AGCOff()
{
	CControlCommand tempCommand(m_ID);
	tempCommand.AddCameraCommand(s_AGCOff, "");
	m_pCommandQueue->AddCommand(tempCommand);
}
//Manual set AGC to low level
void CCamera::AGCLow()
{
	CControlCommand tempCommand(m_ID);
	tempCommand.AddCameraCommand(s_AGCLow, "");
	m_pCommandQueue->AddCommand(tempCommand);
```

```
}
//Manual set AGC to mid level
void CCamera::AGCMid()
{
	CControlCommand tempCommand(m_ID);
	tempCommand.AddCameraCommand(s_AGCMid, "");
	m_pCommandQueue->AddCommand(tempCommand);
}
//Manual set AGC to high level
void CCamera::AGCHigh()
{
	CControlCommand tempCommand(m_ID);
	tempCommand.AddCameraCommand(s_AGCHigh, "");
	m_pCommandQueue->AddCommand(tempCommand);
}
//Automatic focus on
void CCamera::AFOn()
{
	CControlCommand tempCommand(m_ID);
	tempCommand.AddCameraCommand(s_AFOn, "");
	m_pCommandQueue->AddCommand(tempCommand);
}
//Automatic small region focus
void CCamera::AFSmall()
{
	CControlCommand tempCommand(m_ID);
	tempCommand.AddCameraCommand(s_AFSmall, "");
	m_pCommandQueue->AddCommand(tempCommand);
}
//Automatic middle region focus
void CCamera::AFMiddle()
{
	CControlCommand tempCommand(m_ID);
	tempCommand.AddCameraCommand(s_AFMiddle, "");
	m_pCommandQueue->AddCommand(tempCommand);
}
//Automatic large region focus
void CCamera::AFLarge()
{
	CControlCommand tempCommand(m_ID);
	tempCommand.AddCameraCommand(s_AFLarge, "");
	m_pCommandQueue->AddCommand(tempCommand);
}
//Set preset position function
void CCamera::SetPosition(CString Pos)
{
	char buff[5];
	sprintf(buff, "%s", Pos);
	CControlCommand tempCommand(m_ID);
	tempCommand.AddCameraCommand(s_SetPosition, buff);
	m_pCommandQueue->AddCommand(tempCommand);
}
//Goto preset position
void CCamera::GetPosition(CString GPos)
{
	char buff[5];
	sprintf(buff, "%s", GPos);
	CControlCommand tempCommand(m_ID);
	tempCommand.AddCameraCommand(s_GetPosition, buff);
	m_pCommandQueue->AddCommand(tempCommand);
}
//Check IRIS status function
void CCamera::IRISSTATUS()
{
	CControlCommand tempCommand(m_ID);
	tempCommand.AddCameraCommand(s_IRISStatus, "");
	m_pCommandQueue->AddCommand(tempCommand);
}
//Check AGC status function
void CCamera::AGCStatus()
{
	CControlCommand tempCommand(m_ID);
	tempCommand.AddCameraCommand(s_AGCStatus, "");
	m_pCommandQueue->AddCommand(tempCommand);
}
//Check automatic focus status
void CCamera::AFStatus()
{
	CControlCommand tempCommand(m_ID);
	tempCommand.AddCameraCommand(s_AFStatus, "");
	m_pCommandQueue->AddCommand(tempCommand);
}
//Auto sensitivity on
void CCamera::SensAutoOn()
{
	CControlCommand tempCommand(m_ID);
	tempCommand.AddCameraCommand(s_SensAutoOn, "");
	m_pCommandQueue->AddCommand(tempCommand);
}
//Auto sensitivity off
void CCamera::SensAutoOff()
{
	CControlCommand tempCommand(m_ID);
	tempCommand.AddCameraCommand(s_SensAutoOff, "");
	m_pCommandQueue->AddCommand(tempCommand);
}
//Auto sensitivity increase
void CCamera::SensAutoInc()
{
	CControlCommand tempCommand(m_ID);
	tempCommand.AddCameraCommand(s_SensAutoInc, "");
	m_pCommandQueue->AddCommand(tempCommand);
}
////Auto sensitivity decrease
void CCamera::SensAutoDec()
{
	CControlCommand tempCommand(m_ID);
	tempCommand.AddCameraCommand(s_SensAutoDec, "");
	m_pCommandQueue->AddCommand(tempCommand);
}
//check auto sensitivity status
void CCamera::SensAutoStatus()
{
	CControlCommand tempCommand(m_ID);
	tempCommand.AddCameraCommand(s_SensAutoStatus, "");
	m_pCommandQueue->AddCommand(tempCommand);
}
//Manual sensitivity on
void CCamera::SensManualOn()
{
	CControlCommand tempCommand(m_ID);
	tempCommand.AddCameraCommand(s_SensManualOn, "");
	m_pCommandQueue->AddCommand(tempCommand);
}
//Manual sensitivity off
void CCamera::SensManualOff()
{
	CControlCommand tempCommand(m_ID);
	tempCommand.AddCameraCommand(s_SensManualOff, "");
	m_pCommandQueue->AddCommand(tempCommand);
}
//Manual sensitivity increase
void CCamera::SensManualInc()
{
	CControlCommand tempCommand(m_ID);
	tempCommand.AddCameraCommand(s_SensManualInc, "");
	m_pCommandQueue->AddCommand(tempCommand);
}
```

```
//Manual sensitivity decrease
void CCamera::SensManualDec()
{
	CControlCommand tempCommand(m_ID);
	tempCommand.AddCameraCommand(s_SensManualDec, "");
	m_pCommandQueue->AddCommand(tempCommand);
}
//Manual sensitivity status
void CCamera::SensManualStatus()
{
	CControlCommand tempCommand(m_ID);
	tempCommand.AddCameraCommand(s_SensManualStatus, "");
	m_pCommandQueue->AddCommand(tempCommand);
}
//WHite balance ATW on
void CCamera::ATWOn()
{
	CControlCommand tempCommand(m_ID);
	tempCommand.AddCameraCommand(s_ATWOn, "");
	m_pCommandQueue->AddCommand(tempCommand);
}
//White balance AWC on
void CCamera::AWCOn()
{
	CControlCommand tempCommand(m_ID);
	tempCommand.AddCameraCommand(s_AWCOn, "");
	m_pCommandQueue->AddCommand(tempCommand);
}
//AWC reset
void CCamera::AWCReset()
{
	CControlCommand tempCommand(m_ID);
	tempCommand.AddCameraCommand(s_AWCReset, "");
	m_pCommandQueue->AddCommand(tempCommand);
}
//AWC setup
void CCamera::AWCSetup()
{
	CControlCommand tempCommand(m_ID);
	tempCommand.AddCameraCommand(s_AWCSetup, "");
	m_pCommandQueue->AddCommand(tempCommand);
}
//white balance status
void CCamera::WBStatus()
{
	CControlCommand tempCommand(m_ID);
```

```
		tempCommand.AddCameraCommand(s_WBStatus, "");
		m_pCommandQueue->AddCommand(tempCommand);
}
//Shutter speed manual on
void CCamera::ShutterOn()
{
		CControlCommand tempCommand(m_ID);
		tempCommand.AddCameraCommand(s_ShutterOn, "");
		m_pCommandQueue->AddCommand(tempCommand);
}
//shutter speed off (shutter speed = 1/60)
void CCamera::ShutterOff()
{
		CControlCommand tempCommand(m_ID);
		tempCommand.AddCameraCommand(s_ShutterOff, "");
		m_pCommandQueue->AddCommand(tempCommand);
}
//manual increase shutter speed
void CCamera::ShutterInc()
{
		CControlCommand tempCommand(m_ID);
		tempCommand.AddCameraCommand(s_ShutterInc, "");
		m_pCommandQueue->AddCommand(tempCommand);
}
//Manual decrease shutter speed
void CCamera::ShutterDec()
{
		CControlCommand tempCommand(m_ID);
		tempCommand.AddCameraCommand(s_ShutterDec, "");
		m_pCommandQueue->AddCommand(tempCommand);
}
//Shutter speed = 1/100
void CCamera::Shutter100()
{
		CControlCommand tempCommand(m_ID);
		tempCommand.AddCameraCommand(s_Shutter100, "");
		m_pCommandQueue->AddCommand(tempCommand);
}
//Shutter speed = 1/250
void CCamera::Shutter250()
{
		CControlCommand tempCommand(m_ID);
		tempCommand.AddCameraCommand(s_Shutter250, "");
		m_pCommandQueue->AddCommand(tempCommand);
}
//Shutter speed = 1/500
```

```
void CCamera::Shutter500()
{
	CControlCommand tempCommand(m_ID);
	tempCommand.AddCameraCommand(s_Shutter500, "");
	m_pCommandQueue->AddCommand(tempCommand);
}
//Shutter speed = 1/1000
void CCamera::Shutter1000()
{
	CControlCommand tempCommand(m_ID);
	tempCommand.AddCameraCommand(s_Shutter1000, "");
	m_pCommandQueue->AddCommand(tempCommand);
}
//Shutter speed = 1/2000
void CCamera::Shutter2000()
{
	CControlCommand tempCommand(m_ID);
	tempCommand.AddCameraCommand(s_Shutter2000, "");
	m_pCommandQueue->AddCommand(tempCommand);
}
//Shutter speed = 1/4000
void CCamera::Shutter4000()
{
	CControlCommand tempCommand(m_ID);
	tempCommand.AddCameraCommand(s_Shutter4000, "");
	m_pCommandQueue->AddCommand(tempCommand);
}
//Shutter speed = 1/10000
void CCamera::Shutter10000()
{
	CControlCommand tempCommand(m_ID);
	tempCommand.AddCameraCommand(s_Shutter10000, "");
	m_pCommandQueue->AddCommand(tempCommand);
}
//check shutter status
void CCamera::ShutterStatus()
{
	CControlCommand tempCommand(m_ID);
	tempCommand.AddCameraCommand(s_ShutterStatus, "");
	m_pCommandQueue->AddCommand(tempCommand);
}
//Pan right slow
void CCamera::PanRightS()
{
	CControlCommand tempCommand(m_ID);
	tempCommand.AddCameraCommand(s_PanRightS, "");
	m_pCommandQueue->AddCommand(tempCommand);
}
//Pan right fast
void CCamera::PanRightF()
{
	CControlCommand tempCommand(m_ID);
	tempCommand.AddCameraCommand(s_PanRightF, "");
	m_pCommandQueue->AddCommand(tempCommand);
}
//Pan left slow
void CCamera::PanLeftS()
{
	CControlCommand tempCommand(m_ID);
	tempCommand.AddCameraCommand(s_PanLeftS, "");
	m_pCommandQueue->AddCommand(tempCommand);
}
//Pan left fast
void CCamera::PanLeftF()
{
	CControlCommand tempCommand(m_ID);
	tempCommand.AddCameraCommand(s_PanLeftF, "");
	m_pCommandQueue->AddCommand(tempCommand);
}
//Tilt up slow
void CCamera::TiltUpS()
{
	CControlCommand tempCommand(m_ID);
	tempCommand.AddCameraCommand(s_TiltUpS, "");
	m_pCommandQueue->AddCommand(tempCommand);
}
//Tilt down fast
void CCamera::TiltDownF()
{
	CControlCommand tempCommand(m_ID);
	tempCommand.AddCameraCommand(s_TiltDownF, "");
	m_pCommandQueue->AddCommand(tempCommand);
}
//Tilt up fast
void CCamera::TiltUpF()
{
	CControlCommand tempCommand(m_ID);
	tempCommand.AddCameraCommand(s_TiltUpF, "");
	m_pCommandQueue->AddCommand(tempCommand);
}
//Tilt down slow
void CCamera::TiltDownS()
```

```
{
	CControlCommand tempCommand(m_ID);
	tempCommand.AddCameraCommand(s_TiltDownS, "");
	m_pCommandQueue->AddCommand(tempCommand);
}
//Pan right slow and tilt up slow
void CCamera::PanRSTiltUS()
{
	CControlCommand tempCommand(m_ID);
	tempCommand.AddCameraCommand(s_PanRSTiltUS, "");
	m_pCommandQueue->AddCommand(tempCommand);
}
//Pan right slow and tilt up fast
void CCamera::PanRSTiltUF()
{
	CControlCommand tempCommand(m_ID);
	tempCommand.AddCameraCommand(s_PanRSTiltUF, "");
	m_pCommandQueue->AddCommand(tempCommand);
}
//Pan right fast and tilt up slow
void CCamera::PanRFTiltUS()
{
	CControlCommand tempCommand(m_ID);
	tempCommand.AddCameraCommand(s_PanRFTiltUS, "");
	m_pCommandQueue->AddCommand(tempCommand);
}
//pan right fast and tilt up fast
void CCamera::PanRFTiltUF()
{
	CControlCommand tempCommand(m_ID);
	tempCommand.AddCameraCommand(s_PanRFTiltUF, "");
	m_pCommandQueue->AddCommand(tempCommand);
}
//Pan left slow and tilt up slow
void CCamera::PanLSTiltUS()
{
	CControlCommand tempCommand(m_ID);
	tempCommand.AddCameraCommand(s_PanLSTiltUS, "");
	m_pCommandQueue->AddCommand(tempCommand);
}
//Pan left slow and tilt up fast
void CCamera::PanLSTiltUF()
{
	CControlCommand tempCommand(m_ID);
	tempCommand.AddCameraCommand(s_PanLSTiltUF, "");
	m_pCommandQueue->AddCommand(tempCommand);
```

```
}
//Pan left fast and tilt up slow
void CCamera::PanLFTiltUS()
{
	CControlCommand tempCommand(m_ID);
	tempCommand.AddCameraCommand(s_PanLFTiltUS, "");
	m_pCommandQueue->AddCommand(tempCommand);
}
//Pan left fast and tilt up fast
void CCamera::PanLFTiltUF()
{
	CControlCommand tempCommand(m_ID);
	tempCommand.AddCameraCommand(s_PanLFTiltUF, "");
	m_pCommandQueue->AddCommand(tempCommand);
}
//Camera stop moving
void CCamera::CameraStopFF()
{
	CControlCommand tempCommand(m_ID);
	tempCommand.AddCameraCommand(s_CameraStopFF, "");
	m_pCommandQueue->AddCommand(tempCommand);
}
//pan right slow and tilt down slow
void CCamera::panRSTiltDS()
{
	CControlCommand tempCommand(m_ID);
	tempCommand.AddCameraCommand(s_PanRSTiltDS, "");
	m_pCommandQueue->AddCommand(tempCommand);
}
//Pan right slow and tilt down fast
void CCamera::PanRSTiltDF()
{
	CControlCommand tempCommand(m_ID);
	tempCommand.AddCameraCommand(s_PanRSTiltDF, "");
	m_pCommandQueue->AddCommand(tempCommand);
}
//Pan right fast anf tilt down slow
void CCamera::PanRFTiltDS()
{
	CControlCommand tempCommand(m_ID);
	tempCommand.AddCameraCommand(s_PanRFTiltDS, "");
	m_pCommandQueue->AddCommand(tempCommand);
}
//Pan right fast and tilt down fast
void CCamera::PanRFTiltDF()
{
        CControlCommand tempCommand(m_ID);
        tempCommand.AddCameraCommand(s_PanRFTiltDF, "");
        m_pCommandQueue->AddCommand(tempCommand);
}
//Pan left slow anf tilt down slow
void CCamera::PanLSTiltDS()
{
        CControlCommand tempCommand(m_ID);
        tempCommand.AddCameraCommand(s_PanLSTiltDS, "");
        m_pCommandQueue->AddCommand(tempCommand);
}
//Pan leftslow and tilt down fast
void CCamera::PanLSTiltDF()
{
        CControlCommand tempCommand(m_ID);
        tempCommand.AddCameraCommand(s_PanLSTiltDF, "");
        m_pCommandQueue->AddCommand(tempCommand);
}
//Pan left fast anf tilt down slow
void CCamera::PanLFTiltDS()
{
        CControlCommand tempCommand(m_ID);
        tempCommand.AddCameraCommand(s_PanLFTiltDS, "");
        m_pCommandQueue->AddCommand(tempCommand);
}
//Pan left fast and tilt down fast
void CCamera::PanLFTiltDF()
{
        CControlCommand tempCommand(m_ID);
        tempCommand.AddCameraCommand(s_PanLFTiltDF, "");
        m_pCommandQueue->AddCommand(tempCommand);
}
//Pan with coordinate position
void CCamera::Pan(float x)
{
        char buff[5];
        sprintf(buff, "%04d", (int)(x*10)%10000);
        CControlCommand tempCommand(m_ID);
        tempCommand.AddCameraCommand(s_Pan, buff);
        m_pCommandQueue->AddCommand(tempCommand);
}
//Tilt with coordinate position
void CCamera::Tilt(float y)
{
        char buff[5];
        sprintf(buff, "%04d", (int)(y*10)%10000);
        CControlCommand tempCommand(m_ID);
        tempCommand.AddCameraCommand(s_Tilt, buff);
        m_pCommandQueue->AddCommand(tempCommand);
}
```

// **CameraCommand.cpp**: implementation of the CCameraCommand class.

```
//////////////////////////////////////////////////////////////////////
#include "stdafx.h"
//#include "CControl.h"
#include "CameraCommand.h"
#ifdef _DEBUG
#undef THIS_FILE
static char THIS_FILE[]=__FILE__;
#define new DEBUG_NEW
#endif
const char CCameraCommand::s_STX = 0x2;
const char CCameraCommand::s_ETX = 0x3;
const char CCameraCommand::s_ACK = 0x6;
const char CCameraCommand::s_IDSep = ';';
// Construction/Destruction
CCameraCommand::CCameraCommand()
{
}
CCameraCommand::~CCameraCommand()
{
}
//////////////////////////////////////////////////////////////////////
//replace some parameters with command format parameters
CCameraCommand::CCameraCommand(std::string strOut, std::string strIn)
:m_OutString(strOut),
m_InString(strIn)
{
        int i;
        for(i=0; (i = m_OutString.find("[", i)) != std::string::npos; i++) //find "[", replace
with "STX"
        {
                m_OutString[i] = CCameraCommand::s_STX;
        }
        for(i=0; (i = m_OutString.find("]", i)) != std::string::npos; i++) //find "]", replace
with "ETX"
        {
                m_OutString[i] = CCameraCommand::s_ETX;
        }
        for(i=0; (i = m_InString.find("[", i)) != std::string::npos; i++) //find "[", replace
with "STX"
```

```
	{
		m_InString[i] = CCameraCommand::s_STX;
	}
	for(i=0; (i = m_InString.find("]", i)) != std::string::npos; i++) //find "]", replace
with "ETX"
	{
		m_InString[i] = CCameraCommand::s_ETX;
	}
	int iPos;
	for(i = 0, iPos = 0; (iPos = m_OutString.find("*", iPos)) != std::string::npos; i++,
iPos++) m_OutParamPos.insert(m_OutParamPos.end(),iPos);
	for(i = 0, iPos = 0; (iPos = m_InString.find("*", iPos)) != std::string::npos; i++,
iPos++) m_InParamPos.insert(m_InParamPos.end(),iPos);
}
//Is this command a valid command
bool CCameraCommand::ValidCommand(std::string sParam)
{
	if((m_InParamPos.size() <= sParam.length()) && (m_OutParamPos.size() <=
sParam.length())) return true;
	else return true;
}
//insert parameters and camera ID into command
std::string CCameraCommand::GetSendCommand(std::string sParam, std::string
sCameraID)
{
	if(ValidCommand(sParam))
	{
		std::string tempString(m_OutString);
		for(int i = 0; i < m_OutParamPos.size(); i++)
		{
			tempString[m_OutParamPos[i]] = sParam[i];
		}
		if(sCameraID.length() > 0)
		{
			sCameraID.insert(sCameraID.end(), s_IDSep);
			for(int i=0; (i = tempString.find(s_STX, i)) != std::string::npos;
i++)
				tempString.insert(i+1, sCameraID);
		}
		return tempString;
	}
	else return "";
}
//Convert command from standard string to CString
CString CCameraCommand::GetSendCommand(CString sParam, CString sCameraID)
{
	return GetSendCommand(std::string((LPCTSTR)sParam),
(LPCTSTR)sCameraID).c_str();
}
//insert parameters and camera ID into correct answer string
std::string CCameraCommand::GetReceiveCommand(std::string sParam, std::string
sCameraID)
{
	if(ValidCommand(sParam) && sParam.length()>0)
	{
		std::string tempString(m_InString);
		for(int i = 0; i < m_InParamPos.size(); i++)
		{
			tempString[m_InParamPos[i]] = sParam[i];
		}
		if(sCameraID.length() > 0)
		{
			sCameraID.insert(sCameraID.end(), s_IDSep);
			for(int i=0; (i = tempString.find(s_STX, i)) != std::string::npos;
i++)
				tempString.insert(i+1, sCameraID);
		}
		return tempString;
	}
	else
	{
		std::string tempString(m_InString);
		if(sCameraID.length() > 0)
		{
			sCameraID.insert(sCameraID.end(), s_IDSep);
			for(int i=0; (i = tempString.find(s_STX, i)) != std::string::npos;
i++)
				tempString.insert(i+1, sCameraID);
		}
		return tempString;
	}
}
//get correct answer with no parameters
std::string CCameraCommand::GetNoParamReceiveCommand(std::string sCameraID)
{
	std::string tempString(m_InString);
	if(sCameraID.length() > 0)
	{
		sCameraID.insert(sCameraID.end(), s_IDSep);
		for(int i=0; (i = tempString.find(s_STX, i)) != std::string::npos; i++)
			tempString.insert(i+1, sCameraID);
	}
	return tempString;
}
//Convert correct answer from standard string to CString
CString CCameraCommand::GetReceiveCommand(CString sParam, CString
sCameraID)
{
	return GetReceiveCommand(std::string((LPCTSTR)sParam),
(LPCTSTR)sCameraID).c_str();
}
//Compare received answer with correct answer
bool CCameraCommand::CompareToReceived(std::string sCameraID, std::string
strReceived, std::string& sParamOut)
{
	sParamOut.erase(sParamOut.begin(),sParamOut.end());//get rid of the parameters
	std::string tempString = GetNoParamReceiveCommand(sCameraID);
	if(tempString.size() == strReceived.size())
	{
		for(int i=0; (i = tempString.find("*", i)) != std::string::npos; i++)
		{
			sParamOut += strReceived[i];
			strReceived[i] = '*';		//replace parameter in received answer
with "*"
		}
		if(tempString.compare(strReceived) == 0) return true;
	}
	return false;
}

//Convert from standard string to CString
bool CCameraCommand::CompareToReceived(CString sCameraID, CString
strReceived, CString& sParamOut)
{
	std::string tempString;
	bool bReturn = CompareToReceived(std::string((LPCTSTR)sCameraID),
(LPCTSTR)strReceived, tempString);
	sParamOut = tempString.c_str();
	return bReturn;
}

// CommandQueue.cpp : implementation file
// This is the thread which send commands to camera and read answers from camera

#include "stdafx.h"
//#include "myThread.h"
#include "CommandQueue.h"
#include "Serial.h"
```

```
#ifdef _DEBUG
#define new DEBUG_NEW
#undef THIS_FILE
static char THIS_FILE[] = __FILE__;
#endif
#include "resource.h"

//////////////////////////////////////////////////////////////////////
// CCommandQueue
// Construction/Destruction
//////////////////////////////////////////////////////////////////////
IMPLEMENT_DYNCREATE(CCommandQueue, CWinThread)
CCommandQueue::CCommandQueue()
:m_KillThread(false)
{
	m_bAutoDelete = false;
	m_Serial.Open(1,9600);
}
CCommandQueue::CCommandQueue(HWND hParent)
:m_KillThread(false),
m_hParent(hParent)
{
	m_bAutoDelete = false;
	m_Serial.Open(1,9600);
}

CCommandQueue::~CCommandQueue()
{
}
BOOL CCommandQueue::InitInstance()
{
	// TODO:  perform and per-thread initialization here
	return TRUE;
}
int CCommandQueue::ExitInstance()
{
	// TODO:  perform any per-thread cleanup here
	return CWinThread::ExitInstance();
}

BEGIN_MESSAGE_MAP(CCommandQueue, CWinThread)
	//{{AFX_MSG_MAP(CCommandQueue)
		// NOTE - the ClassWizard will add and remove mapping macros here.
	//}}AFX_MSG_MAP
END_MESSAGE_MAP()
```

```
////////////////////////////////////////////////////////////////////////////
// CCommandQueue message handlers
//kill thread function
void CCommandQueue::KillThread()
{
	m_KillThread = true;
	for(int i = ResumeThread(); i != 0 && i != 1; i= ResumeThread());
	WaitForSingleObject((HANDLE)m_ThreadDead,INFINITE);
	delete this;
}
//Run the thread
int CCommandQueue::Run()
{
	// TODO: Add your specialized code here and/or call the base class
	while(!m_KillThread)
	{
		DoWork();
	}
	m_ThreadDead.SetEvent();
	return 0; //ExitInstance();
}
//Send commands
void CCommandQueue::DoWork()
{
	CControlCommand cCommand = GetNextCommand(); //get command
	int iMax = cCommand.m_CommandArray.GetSize(); //get command size
	if(iMax != 0)
	{
		for(int i = 0; i < iMax; i++)
		{
			CCameraCommand* pCa = cCommand.m_CommandArray[i];
			CString theString = pCa-
>GetSendCommand(cCommand.m_ParamArray[i], cCommand.m_CamID);
			m_Serial.SendData((const unsigned char
*)(LPCTSTR)theString);//send command
			theString = WaitCommandAnswer(*pCa,
cCommand.m_ParamArray[i], cCommand.m_CamID);//check answer
			unsigned char buff[2] = " ";
			buff[0] = CCameraCommand::s_ACK;
			m_Serial.SendData(buff);  //Send "ACK" to camera
			PostMessage(m_hParent, WM_SERIALANSWER, 1, 2); //Send
message to other thread for other operation
		}
	}
	else
	{
		SuspendThread(); //Suspend thread
	}
}
//Get ready for next command
CControlCommand CCommandQueue::GetNextCommand()
{
	CControlCommand tempControlCommand;
	CSingleLock csl(&m_CriticalSection);
	csl.Lock();
	if(!m_CommandQ.empty())
	{
		tempControlCommand = m_CommandQ.front();
		m_CommandQ.erase(m_CommandQ.begin());
	}
	csl.Unlock();
	return tempControlCommand;
}
//
void CCommandQueue::AddCommand(CControlCommand cCommand)
{
	CControlCommand* pControlCommand;
	CSingleLock csl(&m_CriticalSection);
	csl.Lock();
	for(std::vector<CControlCommand>::_It it = m_CommandQ.begin(); it <
m_CommandQ.end(); it++)
	{
		pControlCommand = (CControlCommand *)it;
		if(*pControlCommand == cCommand)
			m_CommandQ.erase(pControlCommand);
		int n = m_CommandQ.size();
	}
	m_CommandQ.push_back(cCommand);
	csl.Unlock();
	for(int i = ResumeThread(); i != 0 && i != 1; i= ResumeThread());
}
CString CCommandQueue::WaitCommandAnswer(CCameraCommand& pCa, CString
sParam, CString sCamID, int iTimeOut)
{
	CTime sTime = CTime::GetCurrentTime();
	CString rString = pCa.GetReceiveCommand(sParam, sCamID);
	CString oString;
	CString sParamOut;
	int ilen = rString.GetLength();
	while(!pCa.CompareToReceived(sCamID, oString, sParamOut))
	{
		for(int i = 0; i < ilen;)
```

```
				{
					char buff[2] = " ";
					int iout = m_Serial.ReadData(buff, 1);
					if(iout == 1)
					{
						if(buff[0] == CCameraCommand::s_ACK)
						{
							i = 0;
							oString.Empty();
						}
						else
						{
							i++;
							oString += buff;
						}
					}
					CTime cTime = CTime::GetCurrentTime();
					CTimeSpan ts = cTime-sTime;
					if(ts.GetTotalSeconds() >= iTimeOut/1000)
					{
						AddAnswerString("Time Out Error","");
						return "";
					}
				}
			}
			AddAnswerString(oString,sParamOut);
			return oString;
		}
		void CCommandQueue::AddAnswerString(const CString& str, const CString& strValue)
		{
			CSingleLock csl(&m_AnswerCriticalSection);
			csl.Lock();
			m_Answer.Add(str);
			m_AnswerValue.Add(strValue);
			csl.Unlock();
		}
		CString CCommandQueue::GetAnswerString()
		{
			CString tempString;
			CSingleLock csl(&m_AnswerCriticalSection);
			csl.Lock();
			if(m_Answer.GetSize() > 0)
			{
				tempString = m_Answer[0];
				m_Answer.RemoveAt(0);
			}
```

```
	csl.Unlock();
	return tempString;
}
CString CCommandQueue::GetAnswerValue()
{
	CString tempString;
	CSingleLock csl(&m_AnswerCriticalSection);
	csl.Lock();
	if(m_AnswerValue.GetSize() > 0)
	{
		tempString = m_AnswerValue[0];
		m_AnswerValue.RemoveAt(0);
	}
	csl.Unlock();
	return tempString;
}
```

// **CControlDlg.cpp** : implementation file

```
#include "stdafx.h"
#include "CControl.h"
#include "CControlDlg.h"
#ifdef _DEBUG
#define new DEBUG_NEW
#undef THIS_FILE
static char THIS_FILE[] = __FILE__;
#endif
#ifndef _TIMER_ID
#define _TIMER_ID
#define _ZOOM_TIMER			1
#define _PAN_MOVE_TIMER			2
#define _TILT_MOVE_TIMER	3
#define _START_MOVE_TIMER	4
#endif
/////////////////////////////////////////////////////////////////////////////
// CCControlDlg dialog
CCControlDlg::CCControlDlg(CWnd* pParent /*=NULL*/)
	: CDialog(CCControlDlg::IDD, pParent),
	m_iZoom(0),
	m_Point(0,0),
	m_tPoint(0,0)
{
	//{{AFX_DATA_INIT(CCControlDlg)
	m_strSETPOS = _T("");
	m_strGotoPOS = _T("");
	m_TiltAngle = _T("");
	m_PanAngle = _T("");
	//}}AFX_DATA_INIT
	m_hIcon = AfxGetApp()->LoadIcon(IDR_MAINFRAME);
}
void CCControlDlg::DoDataExchange(CDataExchange* pDX)
{
	CDialog::DoDataExchange(pDX);
	//{{AFX_DATA_MAP(CCControlDlg)
	DDX_Control(pDX, IDC_TILT2, m_Tilt2);
	DDX_Control(pDX, IDC_PAN2, m_Pan2);
	DDX_Control(pDX, IDC_EDIT2, m_Edit2);
	DDX_Control(pDX, IDC_SCROLLBAR2, m_ScrollbarFocus);
	DDX_Control(pDX, IDC_EDITFOCUS, m_EditFocus);
	DDX_Control(pDX, IDC_TILT, m_Tiltangle);
	DDX_Control(pDX, IDC_PAN, m_Panangle);
	DDX_Control(pDX, IDC_ZOOM12, m_Zomm12);
	DDX_Control(pDX, IDC_EDIT1, m_Edit1);
	DDX_CBString(pDX, IDC_SETPOS, m_strSETPOS);
	DDX_CBString(pDX, IDC_COMBOPPOS, m_strGotoPOS);
	DDX_Text(pDX, IDC_EDITTILT, m_TiltAngle);
	DDX_Text(pDX, IDC_EDITPAN, m_PanAngle);
	//}}AFX_DATA_MAP
}
BEGIN_MESSAGE_MAP(CCControlDlg, CDialog)
	//{{AFX_MSG_MAP(CCControlDlg)
	ON_WM_MOUSEWHEEL()
	ON_WM_PAINT()
	ON_WM_QUERYDRAGICON()
	ON_NOTIFY(NM_CUSTOMDRAW, IDC_SLIDER2, OnCustomdrawSlider2)
	ON_BN_CLICKED(IDC_RESET, OnReset)
	ON_BN_CLICKED(IDC_SETPOSITION, OnSetposition)
	ON_BN_CLICKED(IDC_GETPOSITION, OnGetposition)
	ON_WM_LBUTTONDBLCLK()
	ON_BN_CLICKED(IDC_POSITION1, OnPosition1)
	ON_BN_CLICKED(IDC_POSITION2, OnPosition2)
	ON_BN_CLICKED(IDC_POSITION3, OnPosition3)
	ON_BN_CLICKED(IDC_POSITION4, OnPosition4)
	ON_BN_CLICKED(IDC_POSITION5, OnPosition5)
	ON_BN_CLICKED(IDC_POSITION6, OnPosition6)
	ON_BN_CLICKED(IDC_POSITION7, OnPosition7)
	ON_BN_CLICKED(IDC_POSITION8, OnPosition8)
	ON_BN_CLICKED(IDC_POSITION9, OnPosition9)
	ON_BN_CLICKED(IDC_POSITION10, OnPosition10)
	ON_BN_CLICKED(IDC_POSITION11, OnPosition11)
	ON_BN_CLICKED(IDC_POSITION12, OnPosition12)
	ON_BN_CLICKED(IDC_ANGLE, OnAngle)
ON_BN_CLICKED(IDC_GETANGLE, OnGetCameraPosition)
ON_BN_CLICKED(IDC_LIVEON, OnLiveon)
ON_BN_CLICKED(IDC_LIVEOFF, OnLiveoff)
ON_BN_CLICKED(IDC_GETANGLE2, OnGetTiltangle)
ON_BN_CLICKED(IDC_FLIPOFF, OnFlipoff)
ON_BN_CLICKED(IDC_FLIPON, OnFlipon)
ON_BN_CLICKED(IDC_ALCON, OnAlcon)
ON_BN_CLICKED(IDC_IRISOPEN, OnIrisopen)
ON_BN_CLICKED(IDC_IRISCLOSE, OnIrisclose)
ON_BN_CLICKED(IDC_IRISSTOP, OnIrisstop)
ON_BN_CLICKED(IDC_IRISRESET, OnIrisreset)
ON_BN_CLICKED(IDC_MANUAIRIS, OnManuairis)
ON_BN_CLICKED(IDC_AGCON, OnAgcon)
ON_BN_CLICKED(IDC_AGCOFF, OnAgcoff)
ON_BN_CLICKED(IDC_AGCLOW, OnAgclow)
ON_BN_CLICKED(IDC_AGCMID, OnAgcmid)
ON_BN_CLICKED(IDC_AGCHIGH, OnAgchigh)
ON_BN_CLICKED(IDC_AFON, OnAfon)
ON_BN_CLICKED(IDC_AFSMALL, OnAfsmall)
ON_BN_CLICKED(IDC_AFMIDDLE, OnAfmiddle)
ON_BN_CLICKED(IDC_AFLARGE, OnAflarge)
ON_WM_HSCROLL()
ON_THREAD_MESSAGE(WM_SERIALANSWER, OnSerialAnswer)
ON_BN_CLICKED(IDC_IRISSTATUS, OnIrisstatus)
ON_BN_CLICKED(IDC_PANRIGHT, OnPanright)
ON_BN_CLICKED(IDC_AGCSTATUS, OnAgcstatus)
ON_BN_CLICKED(IDC_AFSTATUS, OnAfstatus)
ON_BN_CLICKED(IDC_SENSON, OnSenson)
ON_BN_CLICKED(IDC_SENSOFF, OnSensoff)
ON_BN_CLICKED(IDC_SENSINC, OnSensinc)
ON_BN_CLICKED(IDC_SENSDEC, OnSensdec)
ON_BN_CLICKED(IDC_SENSSTATUS, OnSensstatus)
ON_BN_CLICKED(IDC_SENSONMANUAL, OnSensonmanual)
ON_BN_CLICKED(IDC_SENSOFFMANUAL, OnSensoffmanual)
ON_BN_CLICKED(IDC_SENSINCMANUAL, OnSensincmanual)
ON_BN_CLICKED(IDC_SENSDECMANUAL, OnSensdecmanual)
ON_BN_CLICKED(IDC_SENSSTATUSMANUAL, OnSensstatusmanual)
ON_BN_CLICKED(IDC_ATW, OnAtw)
ON_BN_CLICKED(IDC_AWCON, OnAwcon)
ON_BN_CLICKED(IDC_AWCRESET, OnAwcreset)
ON_BN_CLICKED(IDC_AWCSETUP, OnAwcsetup)
ON_BN_CLICKED(IDC_WBSTATUS, OnWbstatus)
ON_BN_CLICKED(IDC_SHUTTERON, OnShutteron)
ON_BN_CLICKED(IDC_SHUTTEROFF, OnShutteroff)
ON_BN_CLICKED(IDC_SHUTTERINC, OnShutterinc)
ON_BN_CLICKED(IDC_SHUTTERDEC, OnShutterdec)
```

```
	ON_BN_CLICKED(IDC_SHUTTER100, OnShutter100)
	ON_BN_CLICKED(IDC_SHUTTER250, OnShutter250)
	ON_BN_CLICKED(IDC_SHUTTER500, OnShutter500)
	ON_BN_CLICKED(IDC_SHUTTER1000, OnShutter1000)
	ON_BN_CLICKED(IDC_SHUTTER2000, OnShutter2000)
	ON_BN_CLICKED(IDC_SHUTTER4000, OnShutter4000)
	ON_BN_CLICKED(IDC_SHUTTERSTATUS, OnShutterstatus)
	ON_BN_CLICKED(IDC_SHUTTER10000, OnShutter10000)
	ON_WM_LBUTTONUP()
	ON_WM_MOUSEMOVE()
	ON_BN_CLICKED(IDC_TILTUP, OnTiltup)
	ON_BN_CLICKED(IDC_PANLEFT, OnPanleft)
	ON_BN_CLICKED(IDC_TILTDOWN, OnTiltdown)
	ON_BN_CLICKED(IDC_BUTTONMOVE, OnButtonmove)
	ON_BN_CLICKED(IDC_BUTTONCANCLE, OnButtoncancle)
	//}}AFX_MSG_MAP
END_MESSAGE_MAP()
/////////////////////////////////////////////////////////////////////////////
// CCControlDlg message handlers

BOOL CCControlDlg::OnInitDialog()
{
	CDialog::OnInitDialog();
//////////////////////////////////////////////////
//SHould include the following three lines in any other application
///////////////////////////////////////////////////
	m_pCommandQueue = new CCommandQueue(GetSafeHwnd());  //Get curent
window handler
	m_pCommandQueue->CreateThread();			// Create thread
	m_pCamera = new CCamera(m_pCommandQueue, "");//, "AD01", // define
camera ID
	this->EnableScrollBar(SB_HORZ);
	m_pMousePoint=(CStatic *)GetDlgItem(IDC_STATIC1);
	SetIcon(m_hIcon, TRUE);				// Set big icon
	SetIcon(m_hIcon, FALSE);		// Set small icon
	m_pCWnd=GetDlgItem(IDC_STATIC);
	m_pCWnda=GetDlgItem(IDC_STATICNEW);
	m_pSlider=(CSliderCtrl*)GetDlgItem(IDC_SLIDER2);
	m_pSlider->SetTicFreq(10);
	m_pSlider->BringWindowToTop();
	m_pSlider->SetRange(0,210);
	Meteor2= new CskMeteor((this->m_hWnd));
	Meteor2->DisplayOnly();
	m_ScrollbarFocus.SetScrollRange(0, 990);
	m_ScrollbarFocus.SetScrollPos(14);
	int f =14;
	char bufff[5];
	sprintf(bufff, "%5.1f", (float) ((float)(f)/10));
	m_EditFocus.SetWindowText((const char*)bufff);
	return TRUE;  // return TRUE  unless you set the focus to a control
}
void CCControlDlg::OnPaint()
{
	if (IsIconic())
	{
		CPaintDC dc(this); // device context for painting
		SendMessage(WM_ICONERASEBKGND, (WPARAM)
dc.GetSafeHdc(), 0);
		int cxIcon = GetSystemMetrics(SM_CXICON);
		int cyIcon = GetSystemMetrics(SM_CYICON);
		CRect rect;
		GetClientRect(&rect);
		int x = (rect.Width() - cxIcon + 1) / 2;
		int y = (rect.Height() - cyIcon + 1) / 2;
		dc.DrawIcon(x, y, m_hIcon);
	}
	else
	{
		CDialog::OnPaint();
	}
}
HCURSOR CCControlDlg::OnQueryDragIcon()
{
	return (HCURSOR) m_hIcon;
}
void CCControlDlg::OnCustomdrawSlider2(NMHDR* pNMHDR, LRESULT* pResult)
{
	int iZoom = m_pSlider->GetPos();
	char buff[100];
	sprintf(buff,"%d,%d,%5.1f", m_Point.x, m_Point.y, (float) ((float)(iZoom)/10));
	char buffz[5];
	int iZoomp = iZoom + 10;
	sprintf(buffz, "%5.1f", (float) ((float)(iZoomp)/10));
	m_Zomm12.SetWindowText((const char*)buffz);
	this->SetWindowText((LPCSTR)buff);
	if(iZoom != m_iZoom)
	{
		ZoomInCarmera(iZoom);
		m_iZoom=iZoom;
	}
	*pResult = 0;
}
```

```
void CCControlDlg::ZoomInCarmera(int iZoom)
{
	m_pCamera->Zoom(iZoom+10); //  /10.0
}
void CCControlDlg::MoveCamera(float x, float y)  //(int x, int y, int iTimerID)
{
	m_pCamera->MoveToAngle(x, y);// x/10.0
	{
		float Tiltvalue;
		do
		{
		m_pCamera->GetTilt();
		CString TiltValue = m_pCommandQueue->GetAnswerValue();
		Tiltvalue = atof(TiltValue);
		m_pCamera->Tilt(y);// x/10.0
		}while(abs(y-Tiltvalue/10)!=0);
	}

}
void CCControlDlg::OnReset()
{
	m_pCamera->Reset();
}
void CCControlDlg::OnSetposition()
{
	UpdateData(TRUE);
	CString sSetpos = m_strSETPOS;
	m_pCamera->SetPosition(sSetpos);
}
void CCControlDlg::OnGetposition()
{
	UpdateData(TRUE);
	CString sGetpos = m_strGotoPOS;
	m_pCamera->GetPosition(sGetpos);
}
void CCControlDlg::OnLButtonDblClk(UINT nFlags, CPoint point)
{
	CRect rect;
	m_pCWnd->GetClientRect(&rect);
	CPoint thePoint(point);
	MapWindowPoints(m_pCWnd,&thePoint,1);
	if(rect.PtInRect(thePoint))
	{
		CClientDC dc(this);
		m_pMousePoint->MoveWindow(point.x,point.y, 3, 3);
		thePoint.x = thePoint.x - (rect.left + rect.right)/2;
```

```
                thePoint.y = (rect.top + rect.bottom)/2 - thePoint.y;
                char buff[100];
                sprintf(buff,"%d,%d,%5.1f",thePoint.x,thePoint.y,m_pSlider-
>GetPos()/10);//  /10
                this->SetWindowText((LPCSTR)buff);
                thePoint.x = 180 - thePoint.x;
                thePoint.y = 90 - thePoint.y;
                if (thePoint.y>90)
                {
                        thePoint.y = 180-thePoint.y;
                }
                else
                {
                        thePoint.y = thePoint.y;
                }
                char buffp[5];
                sprintf(buffp, "%5.1f", (float) ((float)(thePoint.x)));
                m_Panangle.SetWindowText((const char*)buffp);
                char bufft[5];
                sprintf(bufft, "%5.1f", (float) ((float)(thePoint.y)));
                m_Tiltangle.SetWindowText((const char*)bufft);
                MoveCamera(thePoint.x,thePoint.y);
        }
        CDialog::OnLButtonDblClk(nFlags, point);
}
void CCControlDlg::OnPosition1()
{
        m_pCamera->GotoPosition(1);
}
void CCControlDlg::OnPosition2()
{
        m_pCamera->GotoPosition(2);
}
void CCControlDlg::OnPosition3()
{
        m_pCamera->GotoPosition(3);
}
void CCControlDlg::OnPosition4()
{
        m_pCamera->GotoPosition(4);
}
void CCControlDlg::OnPosition5()
{
        m_pCamera->GotoPosition(5);
}
void CCControlDlg::OnPosition6()
```

```
{
	m_pCamera->GotoPosition(6);
}
void CCControlDlg::OnPosition7()
{
	m_pCamera->GotoPosition(7);
}
void CCControlDlg::OnPosition8()
{
	m_pCamera->GotoPosition(8);
}
void CCControlDlg::OnPosition9()
{
	m_pCamera->GotoPosition(9);
}
void CCControlDlg::OnPosition10()
{
	m_pCamera->GotoPosition(10);
}
void CCControlDlg::OnPosition11()
{
	m_pCamera->GotoPosition(11);
}
void CCControlDlg::OnPosition12()
{
	m_pCamera->GotoPosition(12);
}
int CCControlDlg::ReadFeedback(unsigned char *cData, int iSize)//unsigned
{
	int iStatus=0;
	return iStatus;
}
void CCControlDlg::OnAngle()
{
	m_pCamera->HomePosition();
}
void CCControlDlg::OnGetCameraPosition()
{
	m_pCamera->GetPan();
}
BOOL CCControlDlg::OnMouseWheel(UINT nFlags, short zDelta, CPoint pt)
{
	int iMove=zDelta/-119;
	m_pSlider->SetPos(m_pSlider->GetPos()+iMove);
	return CDialog::OnMouseWheel(nFlags,zDelta,pt);
}
```

```
int CCControlDlg::FindString(char *str1, char *str2)
{
	std::string Instr(str1);
	return Instr.rfind(str2);
}
void CCControlDlg::OnLiveon()
{
	if (Meteor2->GrabIsStarted==FALSE)
	{
		MdigGrabContinuous(Meteor2->MilDigitizer, Meteor2->MilImageChild);
		Meteor2->GrabIsStarted=TRUE;
	}
}
void CCControlDlg::OnLiveoff()
{
	Meteor2->HaltGrab();
}
void CCControlDlg::OnGetTiltangle()
{
	m_pCamera->GetTilt();
}
void CCControlDlg::OnFlipoff()
{

	unsigned char szData2[]="0GC7: 903004E0";
	szData2[0]=0x2;szData2[strlen((const char *)szData2)-1]=0x3;
}

void CCControlDlg::OnFlipon()
{
	unsigned char szData2[]="0GC7: 903004D0";
	szData2[0]=0x2;szData2[strlen((const char *)szData2)-1]=0x3;
}
void CCControlDlg::OnAlcon()
{
	m_pCamera->ALCOn();
}
void CCControlDlg::OnIrisopen()
{
	m_pCamera->IRISOpen();
}
void CCControlDlg::OnIrisclose()
{
	m_pCamera->IRISClose();
}
void CCControlDlg::OnIrisstop()
```

```
{
	m_pCamera->IRISStop();
}
void CCControlDlg::OnIrisreset()
{
	m_pCamera->IRISReset();
}
void CCControlDlg::OnManuairis()
{
	m_pCamera->IRISManual();
}
void CCControlDlg::OnAgcon()
{
	m_pCamera->AGCOn();
}
void CCControlDlg::OnAgcoff()
{
	m_pCamera->AGCOff();
}
void CCControlDlg::OnAgclow()
{
	m_pCamera->AGCLow();
}
void CCControlDlg::OnAgcmid()
{
	m_pCamera->AGCMid();
}
void CCControlDlg::OnAgchigh()
{
	m_pCamera->AGCHigh();
}
void CCControlDlg::OnAfon()
{
	m_pCamera->AFOn();
}
void CCControlDlg::OnAfsmall()
{
	m_pCamera->AFSmall();
}
void CCControlDlg::OnAfmiddle()
{
	m_pCamera->AFMiddle();
}
void CCControlDlg::OnAflarge()
{
	m_pCamera->AFLarge();
```

```
}
void CControlDlg::OnHScroll(UINT nSBCode, UINT nPos, CScrollBar* pScrollBar)
{
        int iNowfocus;
        switch (nSBCode)
        {
        if(pScrollBar == &m_ScrollbarFocus)
                {
                case SB_THUMBTRACK:
                        m_ScrollbarFocus.SetScrollPos(nPos);
                        iNowfocus = m_ScrollbarFocus.GetScrollPos();
                        CameraFocus(iNowfocus);
                        break;
                case SB_LINEDOWN:
                        iNowfocus = m_ScrollbarFocus.GetScrollPos();
                        iNowfocus = iNowfocus +1;
                        if (iNowfocus>990)
                                iNowfocus=990;
                        m_ScrollbarFocus.SetScrollPos(iNowfocus);
                        CameraFocus(iNowfocus);
                        break;
                case SB_LINEUP:
                        iNowfocus = m_ScrollbarFocus.GetScrollPos();
                        iNowfocus = iNowfocus -1;
                        if (iNowfocus<14)
                                iNowfocus=14;
                        m_ScrollbarFocus.SetScrollPos(iNowfocus);
                        CameraFocus(iNowfocus);
                        break;
                case SB_PAGEDOWN:
                        iNowfocus = m_ScrollbarFocus.GetScrollPos();
                        iNowfocus = iNowfocus +10;
                        if (iNowfocus>990)
                                iNowfocus=990;
                        m_ScrollbarFocus.SetScrollPos(iNowfocus);
                        CameraFocus(iNowfocus);
                        break;
                case SB_PAGEUP:
                        iNowfocus = m_ScrollbarFocus.GetScrollPos();
                        iNowfocus = iNowfocus - 10;
                        if (iNowfocus<14)
                                iNowfocus=14;
                        m_ScrollbarFocus.SetScrollPos(iNowfocus);
                        CameraFocus(iNowfocus);
                        break;
                }
```

```
	}
	CDialog::OnHScroll(nSBCode, nPos, pScrollBar);
}
void CCControlDlg::CameraFocus(int iNowfocus)
{
	char bufff[5];
	sprintf(bufff, "%5.1f", (float) ((float)(iNowfocus)/10));
	m_EditFocus.SetWindowText((const char*)bufff);

	m_pCamera->Focuse(iNowfocus/10.0);
}
//Destroy windows and kill thread
BOOL CCControlDlg::DestroyWindow()
{
	m_pCommandQueue->KillThread();
	delete m_pCamera;
	return CDialog::DestroyWindow();
}
//Handle message from thread and show information in edit box
void CCControlDlg::OnSerialAnswer(UINT wParam, LONG lParam)
{
	char buff[40];
	sprintf(buff,"%x,%x", wParam, lParam);
	m_Edit1.SetWindowText(m_pCommandQueue->GetAnswerString());
	m_Edit2.SetWindowText(m_pCommandQueue->GetAnswerValue());
}
void CCControlDlg::OnIrisstatus()
{
	m_pCamera->IRISSTATUS();
}
void CCControlDlg::OnPanright()
{
	m_pCamera->PanRightF();
}
void CCControlDlg::OnAgcstatus()
{
	m_pCamera->AGCStatus();
}
void CCControlDlg::OnAfstatus()
{
	m_pCamera->AFStatus();
}
void CCControlDlg::OnSenson()
{
	m_pCamera->SensAutoOn();
}
```

```
void CCControlDlg::OnSensoff()
{
	m_pCamera->SensAutoOff();
}
void CCControlDlg::OnSensinc()
{
	m_pCamera->SensAutoInc();
}
void CCControlDlg::OnSensdec()
{
	m_pCamera->SensAutoDec();
}
void CCControlDlg::OnSensstatus()
{
	m_pCamera->SensAutoStatus();
}
void CCControlDlg::OnSensonmanual()
{
	m_pCamera->SensManualOn();
}
void CCControlDlg::OnSensoffmanual()
{
	m_pCamera->SensManualOff();
}
void CCControlDlg::OnSensincmanual()
{
	m_pCamera->SensManualInc();
}
void CCControlDlg::OnSensdecmanual()
{
	m_pCamera->SensManualDec();
}
void CCControlDlg::OnSensstatusmanual()
{
	m_pCamera->SensManualStatus();
}
void CCControlDlg::OnAtw()
{
	m_pCamera->ATWOn();

}
void CCControlDlg::OnAwcon()
{
	m_pCamera->AWCOn();
}
void CCControlDlg::OnAwcreset()
```

```
{
        m_pCamera->AWCReset();
}
void CControlDlg::OnAwcsetup()
{
        m_pCamera->AWCSetup();
}
void CControlDlg::OnWbstatus()
{
        m_pCamera->WBStatus();
}
void CControlDlg::OnShutteron()
{
        m_pCamera->ShutterOn();
}
void CControlDlg::OnShutteroff()
{
        m_pCamera->ShutterOff();
}
void CControlDlg::OnShutterinc()
{
        m_pCamera->ShutterInc();
}
void CControlDlg::OnShutterdec()
{
        m_pCamera->ShutterDec();
}
void CControlDlg::OnShutter100()
{
        m_pCamera->Shutter100();
}

void CControlDlg::OnShutter250()
{
        m_pCamera->Shutter250();
}
void CControlDlg::OnShutter500()
{
        m_pCamera->Shutter500();
}
void CControlDlg::OnShutter1000()
{
        m_pCamera->Shutter1000();
}
void CControlDlg::OnShutter2000()
{
	m_pCamera->Shutter2000();
}
void CCControlDlg::OnShutter4000()
{
	m_pCamera->Shutter4000();
}
void CCControlDlg::OnShutterstatus()
{
	m_pCamera->ShutterStatus();
}
void CCControlDlg::OnShutter10000()
{
	m_pCamera->Shutter10000();
}
void CCControlDlg::CameraMove(float x, float y)
{
	if(abs(y)<= 5*(abs(x))/100)
	{
		if(x>0 && x<=50)
		{
			m_pCamera->PanRightS();
		}
		else
		if(x>50 && x<=100)
		{
			m_pCamera->PanRightF();
		}
		else
		if(x<0 && x>=-50)
		{
			m_pCamera->PanLeftS();
		}
		else
		{
			m_pCamera->PanLeftF();

		}
	}
	else
	if(abs(x)<= 5*(abs(y))/100)
	{
		if(y>0 && y<=50)
		{
			m_pCamera->TiltUpS();
		}
		else
		if(y>50 && y<=100)
		{
			m_pCamera->TiltUpF();
		}
		else
		if(y<0 && y>=-50)
		{
			m_pCamera->TiltDownS();
		}
		else
		{
			m_pCamera->TiltDownF();
		}
	}
	else
	if(abs(y)>= 5*(abs(x))/100 && abs(y)<abs(x) && y>0)
	{
		if(x>0 && x<=50)
		{
			m_pCamera->PanRFTiltUS();
		}
		else
		if(x>50 && x<=100)
		{
			m_pCamera->PanRFTiltUF();
		}
		else
		if(x<0 && x>=-50)
		{
			m_pCamera->PanLFTiltUS();
		}
		else
		{
			m_pCamera->PanLFTiltUF();

		}
	}
	else
	if(abs(y)>= 5*(abs(x))/100 && abs(y)<abs(x) && y<0)
	{
		if(x>0 && x<=50)
		{
			m_pCamera->PanRFTiltDS();
		}
		else
		if(x>50 && x<=100)
```

```
        {
                m_pCamera->PanRFTiltDF();
        }
        else
        if(x<0 && x>=-50)
        {
                m_pCamera->PanLFTiltDS();
        }
        else
        {
                m_pCamera->PanLFTiltDF();
        }
}
else
if(abs(x)>= 5*(abs(y))/100 && abs(x)<abs(y) && x>0)
{
        if(y>0 && y<=50)
        {
                m_pCamera->PanRSTiltUF();
        }
        else
        if(y>50 && y<=100)
        {
                m_pCamera->PanRSTiltUF();
        }
        else
        if(y<0 && y>=-50)
        {
                m_pCamera->PanRSTiltDF();
        }
        else
        {
                m_pCamera->PanRSTiltDF();
        }
}
else
if(abs(x)>= 5*(abs(y))/100 && abs(x)<abs(y) && x<0)
{
        if(y>0 && y<=50)
        {
                m_pCamera->PanLSTiltUF();
        }
        else
        if(y>50 && y<=100)
        {
                m_pCamera->PanLSTiltUF();
```

```
				}
				else
				if(y<0 && y>=-50)
				{
					m_pCamera->PanLSTiltDF();
				}
				else
				{
					m_pCamera->PanLSTiltDF();

				}
		}
}

void CControlDlg::OnLButtonUp(UINT nFlags, CPoint point)
{
		// TODO: Add your message handler code here and/or call default
				CRect rect;
				m_pCWnda->GetClientRect(&rect);
				CPoint thePoint(point);
				MapWindowPoints(m_pCWnda,&thePoint,1);
				if(rect.PtInRect(thePoint))
				{
					m_pCamera->CameraStopFF();
				}

		CDialog::OnLButtonUp(nFlags, point);
}



void CControlDlg::OnMouseMove(UINT nFlags, CPoint point)
{
		// TODO: Add your message handler code here and/or call default
		if((nFlags & MK_LBUTTON) == MK_LBUTTON)
		{
				CRect rect;
				m_pCWnda->GetClientRect(&rect);
				CPoint thePoint(point);
				MapWindowPoints(m_pCWnda,&thePoint,1);
				if(rect.PtInRect(thePoint))
				{
					thePoint.x = thePoint.x - (rect.left + rect.right)/2;
					thePoint.y = (rect.top + rect.bottom)/2 - thePoint.y;
					char buff[100];
					sprintf(buff,"%d,%d",thePoint.x,thePoint.y);
```

```
                this->SetWindowText((LPCSTR)buff);
                CameraMove(float (thePoint.x),float (thePoint.y));
            }
        }
        else
        {
            CRect rect;
            m_pCWnd->GetClientRect(&rect);
            CPoint thePoint(point);
            MapWindowPoints(m_pCWnd,&thePoint,1);
            if(rect.PtInRect(thePoint))
            {
                CClientDC dc(this);
//              m_pMousePoint->MoveWindow(point.x,point.y, 3, 3);
                thePoint.x = thePoint.x - (rect.left + rect.right)/2;
                thePoint.y = (rect.top + rect.bottom)/2 - thePoint.y;
                char buff[100];
                sprintf(buff,"%d,%d,%5.1f",thePoint.x,thePoint.y,m_pSlider-
>GetPos()/10);//  /10
                this->SetWindowText((LPCSTR)buff);

                thePoint.x = 180 - thePoint.x;
                thePoint.y = 90 - thePoint.y;

                if (thePoint.y>90)
                {
                    thePoint.y = 180-thePoint.y;
                }
                else
                {
                    thePoint.y = thePoint.y;
                }
                char buffp[5];
                sprintf(buffp, "%5.1f", (float) ((float)(thePoint.x)));
                m_Pan2.SetWindowText((const char*)buffp);

                char bufft[5];
                sprintf(bufft, "%5.1f", (float) ((float)(thePoint.y)));
                m_Tilt2.SetWindowText((const char*)bufft);
            }
        }
        CDialog::OnMouseMove(nFlags, point);
}
void CCControlDlg::OnTiltup()
{
        // TODO: Add your control notification handler code here
        m_pCamera->TiltUpF();
}
void CCControlDlg::OnPanleft()
{
        // TODO: Add your control notification handler code here
        m_pCamera->PanLeftF();
}
void CCControlDlg::OnTiltdown()
{
        // TODO: Add your control notification handler code here
        m_pCamera->TiltDownF();
}
void CCControlDlg::OnButtonmove()
{
        // TODO: Add your control notification handler code here
        UpdateData(TRUE);
        CString PanAngle = m_PanAngle;
        float PanAN = atof(PanAngle);
        CString TiltAngle = m_TiltAngle;
        float TiltAN = atof(TiltAngle);
        UpdateData(FALSE);
        MoveCamera(PanAN,TiltAN);
}
void CCControlDlg::OnButtoncancle()
{
        // TODO: Add your control notification handler code here
        m_PanAngle = "";
        m_TiltAngle = "";
        UpdateData(FALSE);
}
```

// Serial.cpp

```
#include "stdafx.h"
#include "Serial.h"
CSerial::CSerial()
{
        m_hIDComDev = NULL;
        m_bOpened = FALSE;
}
CSerial::~CSerial()
{
        Close();
}
BOOL CSerial::Open( int nPort, int nBaud )
{
	if( m_bOpened ) return( TRUE );
	char szPort[15];
	char szComParams[50];
	DCB dcb;
	wsprintf( szPort, "COM%d", nPort );
	m_hIDComDev = CreateFile( szPort, GENERIC_READ | GENERIC_WRITE, 0,
NULL, OPEN_EXISTING, FILE_ATTRIBUTE_NORMAL |
FILE_FLAG_OVERLAPPED, NULL ); //| FILE_FLAG_OVERLAPPED
FILE_ATTRIBUTE_NORMAL | FILE_FLAG_OVERLAPPED
	if( m_hIDComDev == NULL ) return( FALSE );
	memset( &m_OverlappedRead, 0, sizeof( OVERLAPPED ) );
	memset( &m_OverlappedWrite, 0, sizeof( OVERLAPPED ) );
	COMMTIMEOUTS CommTimeOuts;
	CommTimeOuts.ReadIntervalTimeout = 0xFFFFFFFF;
	CommTimeOuts.ReadTotalTimeoutMultiplier = 0;
	CommTimeOuts.ReadTotalTimeoutConstant = 0;
	CommTimeOuts.WriteTotalTimeoutMultiplier = 0;
	CommTimeOuts.WriteTotalTimeoutConstant = 5000;
	SetCommTimeouts( m_hIDComDev, &CommTimeOuts );
	wsprintf( szComParams, "COM%d:%d,n,8,1", nPort, nBaud );
	m_OverlappedRead.hEvent = CreateEvent( NULL, TRUE, FALSE, NULL );
	m_OverlappedWrite.hEvent = CreateEvent( NULL, TRUE, FALSE, NULL );
	dcb.DCBlength = sizeof( DCB );
	GetCommState( m_hIDComDev, &dcb );
	dcb.BaudRate = nBaud;
	dcb.ByteSize = 8;
	dcb.Parity = 0;
	dcb.StopBits = 0;
	unsigned char ucSet;
	ucSet = (unsigned char) ( ( FC_RTSCTS & FC_DTRDSR ) != 0 );
	ucSet = (unsigned char) ( ( FC_RTSCTS & FC_RTSCTS ) != 0 );
	ucSet = (unsigned char) ( ( FC_RTSCTS & FC_XONXOFF ) != 0 );
	int iComStatus = SetCommState( m_hIDComDev, &dcb );
	int iSetCom = SetupComm( m_hIDComDev, 20, 20);
	if( !iComStatus ||
		!iSetCom ||
		m_OverlappedRead.hEvent == NULL ||
		m_OverlappedWrite.hEvent == NULL ){
		DWORD dwError = GetLastError();
		if( m_OverlappedRead.hEvent != NULL ) CloseHandle(
m_OverlappedRead.hEvent );
		if( m_OverlappedWrite.hEvent != NULL ) CloseHandle(
m_OverlappedWrite.hEvent );
		CloseHandle( m_hIDComDev );
		return( FALSE );
		}
	m_bOpened = TRUE;
	return( m_bOpened );
}
BOOL CSerial::Close( void )
{
	if( !m_bOpened || m_hIDComDev == NULL ) return( TRUE );
	if( m_OverlappedRead.hEvent != NULL ) CloseHandle( 
m_OverlappedRead.hEvent );
	if( m_OverlappedWrite.hEvent != NULL ) CloseHandle( 
m_OverlappedWrite.hEvent );
	CloseHandle( m_hIDComDev );
	m_bOpened = FALSE;
	m_hIDComDev = NULL;
	return( TRUE );
}
BOOL CSerial::WriteCommByte( unsigned char ucByte )
{
	BOOL bWriteStat;
	DWORD dwBytesWritten;
	bWriteStat = WriteFile( m_hIDComDev, (LPSTR) &ucByte, 1, 
&dwBytesWritten, &m_OverlappedWrite );
	if( !bWriteStat && ( GetLastError() == ERROR_IO_PENDING ) )
	{
		if(WaitForSingleObject( m_OverlappedWrite.hEvent, 1000 ) )
			dwBytesWritten = 0;
		else
		{
			GetOverlappedResult( m_hIDComDev, &m_OverlappedWrite, 
&dwBytesWritten, FALSE );
			m_OverlappedWrite.Offset += dwBytesWritten;
		}
	}
	return( TRUE );
}
int CSerial::SendData( const unsigned char *buffer, int size )
{
	if( !m_bOpened || m_hIDComDev == NULL ) return( 0 );
	DWORD dwBytesWritten = 0;
	int i;
	if(size==0) size=strlen((const char*)buffer);
	for( i=0; i<size; i++ ){
		WriteCommByte( buffer[i] );
		dwBytesWritten++;
		}
	return( (int) dwBytesWritten );
}
```

```
int CSerial::ReadDataWaiting( void )
{
        if( !m_bOpened || m_hIDComDev == NULL ) return( 0 );
        DWORD dwErrorFlags;
        COMSTAT ComStat;
        ClearCommError( m_hIDComDev, &dwErrorFlags, &ComStat );
        return( (int) ComStat.cbInQue );
}
int CSerial::ReadData( void *buffer, int limit )
{
        if( !m_bOpened || m_hIDComDev == NULL ) return( 0 );
        BOOL bReadStatus;
        DWORD dwBytesRead, dwErrorFlags;
        COMSTAT ComStat;
        ClearCommError( m_hIDComDev, &dwErrorFlags, &ComStat );
//      if( !ComStat.cbInQue ) return( 0 );
        dwBytesRead = (DWORD) ComStat.cbInQue;
        if( limit < (int) dwBytesRead ) dwBytesRead = (DWORD) limit;
        bReadStatus = ReadFile( m_hIDComDev, buffer, dwBytesRead, &dwBytesRead,
&m_OverlappedRead );
        if( !bReadStatus ){
                if( GetLastError() == ERROR_IO_PENDING ){
                        WaitForSingleObject( m_OverlappedRead.hEvent, 2000 );
                        return( (int) dwBytesRead );
                        }
                return( 0 );
                }
//      m_OverlappedRead.Offset += dwBytesRead;//limit;
        return( (int) dwBytesRead );
}
```