WIRELESS DIGITAL VIDEO CAMERA

Design Document

by

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1 Abstract

The objective of the project is to build a cheap wireless monitoring system for slowly varying environments. The system can be used to monitor bee hives, house solar panels and activities in the compound. The system consists of two IEEE802.15.4 Standard-compliant wireless transceiver modules and microcontrollers, a CMOS digital camera, PC Graphical User Interface (GUI) and serial port modules. The wireless transceiver modules communicate between the camera-side embedded system and the PC-side embedded system. The sequence of images sent from the camera-side transceiver is received wirelessly by the PC-side transceiver. The PC-side transceiver then transfers the images to the PC via the PC's serial port. The sequence of images is displayed in the GUI. The GUI also features recording, playback of recording and deletion of recording functions, controllable by the user through the GUI.

2 Design and implementation

This section is divided into hardware architecture, embedded software architecture and host software architecture. The hardware architecture section describes the functions and the interactions between the components of the system. The embedded software architecture section describes the embedded software and protocols that handle wireless transmission and camera operation. The host software architecture section describes the PC GUI program that handles user commands and video display.

2.1 Hardware architecture

2.1.1 Overview

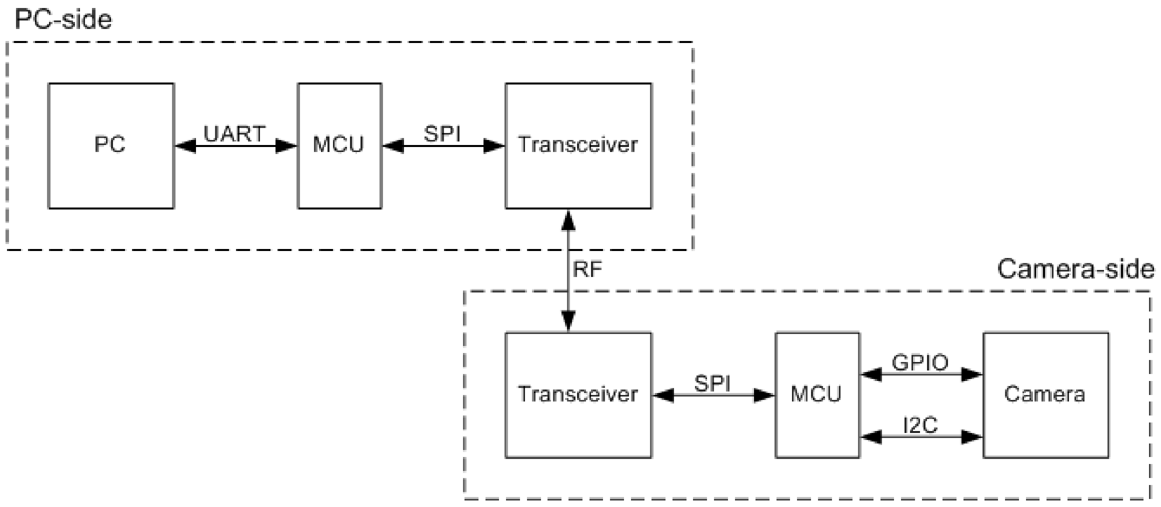


Figure 1 - Hardware top level diagram

The major components of the system are the PC, two microcontrollers (MCU), two wireless RF transceivers and a CMOS camera. The MCUs used are the Atmel Atmega644P. The transceivers used are the Atmel AT86RF230 chips. The CMOS camera used is the C3088 video camera with Omnivision OV6620 image sensor. The components can generally be grouped into PC-side components and camera-side components as shown in Figure 1.

The PC-side-MCU is responsible for receiving data via SPI from the RF transceiver connected to it and then sends the data over to the PC via UART. Reading and writing to the transceiver's registers are also done through SPI whereby the MCU is set as the master and the transceiver the slave.

The camera-side-MCU is responsible for controlling the RF transceiver and the camera connected to it and receiving image data from the camera. The camera's image data is clocked out onto its output pins which are connected to the general purpose input output (GPIO) ports of the MCU. The MCU retrieves the image data and sends it to the transceiver for transmission. Image transmission will be discussed further in the embedded software architecture section. Reading and writing to the camera's registers are done through I^2C (or TWI).

2.1.2 MCU

The Atmega644P MCU is chosen because of its large SRAM capacity (4 KB) which makes buffering of data easier. It is capable of running at low voltages at low frequencies. Because of the operating voltage of the RF transceiver is 3.6V, the MCU is designed to operate at 3.6V as well. At 3.6V, the MCU is guaranteed to run properly below 10MHz. Therefore the operating frequency of the MCU is set to 8MHz.

For convenience and ease of verification, I started the design with Professor Land's MCU PCB as shown below. The MCU GPIO ports as well as Vcc and Gnd pins are wired to pins along the edge of the PCB. The order and layout of these pins are important in designing the PCB for the RF transceiver which will be discussed in the next section.

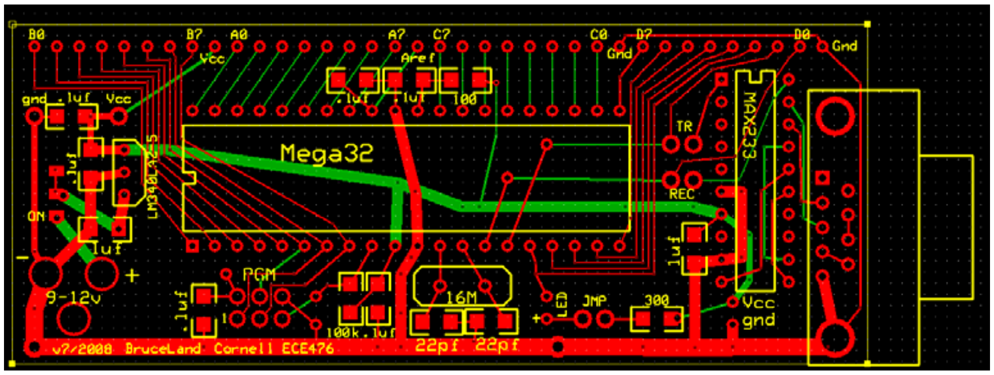


Figure 2 - MCU circuit board

The PCB is designed for 5V operation with the LM340 5V regulator. I made a slight modification to the 5V regulator to provide 3.6V to the MCU. The 5V output pin of the 5V regulator is disconnected from the PCB and connected to the input pin of a 3.6V regulator which is on the RF transceiver PCB. The output of the 3.6V regulator is then sent back to the MCU PCB via the VCC pins. See Section 2.1.5 for power supply details.

The following table summarizes all the GPIO pins used. There are 11 free GPIO ports that can still be used for other purposes.

Ports	Pins	Connections	Comments
Port A	A0	Y0	Connected to the camera
	A1	Y1	
	A2	Y2	
	A3	Y3	
	A4	Y4	
	A5	Y5	
	A6	Y6	
	A7	Y7	
Port B	B0	NC	Connected to the RF transceiver
	B1	/RST	
	B2	IRQ	
	B3	SLP_TR	
	B4	/SEL	

	B5	MOSI	
	B6	MISO	
	B7	SCLK	
Port C	C0	SCL	Connected to the camera
	C1	SDA	
Port D	D2	VSYNC	
	D3	HREF	
	D4	PCLK	

Table 1 - GPIO connections

2.1.3 RF transceiver

The AT86RF230 transceiver operates at a voltage of 3.6V and frequency of 16MHz. A Balun is used to convert its balanced output signal to unbalanced signal that is fed to the antenna. The controls of the RF transceiver are connected to Port B of the MCU as shown in Table 1. Data is transferred between the transceiver and the MCU via SPI. The SPI control pins are /SEL, MOSI, MISO and SCLK. The MCU is the master whereas the transceiver is the slave in this SPI relationship. The MCU supplies the clock signal via the SCLK pin. To initialize communication, the MCU pulls the /SEL pin low and data is sent to the transceiver through the MOSI pin and received from the transceiver through the MISO pin. A low signal on the /RST pin resets the transceiver. The SLP_TR pin is used to start a wireless transmission of a frame of data.

2.1.4 Camera

The C3088 camera operates at a voltage of 5V. It has a built in crystal that oscillates at 17.73MHz. It is capable of taking relatively high resolution images at 101,376 pixels. The difference in operating voltage between the camera (at 5V) and the rest of the circuit (at 3.6V) does not pose an issue because only the camera's digital IO pins are receiving signals from the rest of the system's circuit. The camera's digital IO pins used for I^2C communication are able to accept lower range of voltage values at 3.6V from the MCU GPIO pins. The image data received by the MCU, no doubt has a maximum voltage level of 5V, can still be handled appropriately by the MCU.

The C3088 camera has 32 pins in a 2-by-16 pin arrangement. A standard 2x16 connector is used to connect the camera's pins to the PCB.

2.1.5 Power supply

The system consists of three power supply sources. The main power supply provides 9V. The 5V regulator (LM340) converts the 9V DC supply to 5V to power the camera circuit and the 3.6V regulator. The 3.6V regulator (LP2985) converts the 5V supply to 3.6V to power the MCU and transceiver circuits.

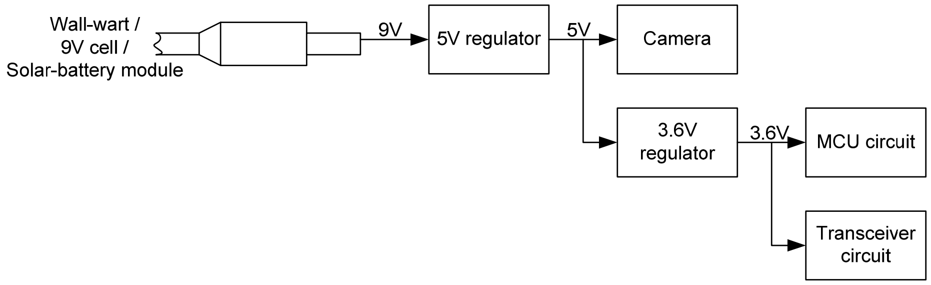


Figure 3 - Power supply

2.1.6 Connectors

As shown in the schematic diagram, there are altogether 5 connectors (J1, J2, J3, J4 and J5) used in the PC-side and camera-side PCB design. The PC-side PCB has only the transceiver circuitry whereas the camera-side PCB has both the transceiver and camera circuitries. Therefore the PC-side PCB only requires one connector - J1. The camera-side PCB uses all 5 connectors – J1, J2, J3, J4 and J5.

Connectors J1 and J2 interface with the GPIO, VCC and GND pins aligned along the edge of the MCU PCB. Connector J3 interfaces with the pins on the C3088 camera. Connector J4 is an auxiliary connector that duplicates the camera UV pins for ease of feature expansion in the future. Connector J5 is also an auxiliary connector that duplicates the MCU's Port C pins.

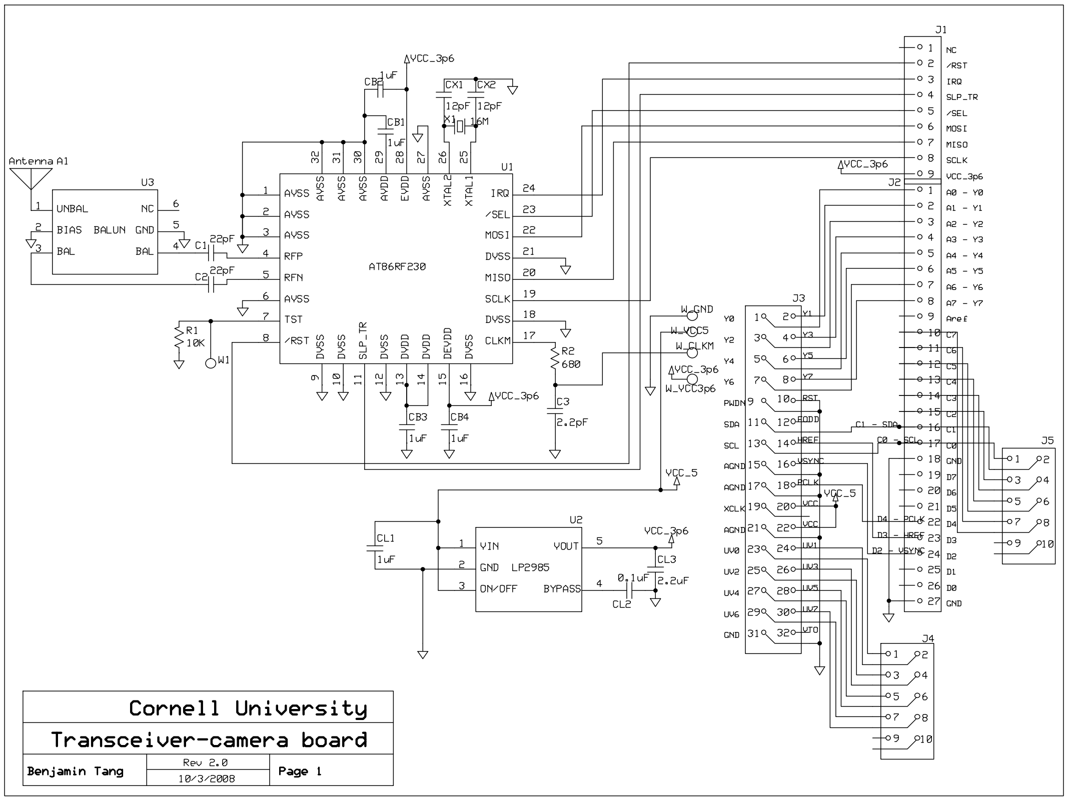


Figure 4 - Schematic diagram for transceiver-camera board

2.1.7 Layout

The cheapest PCB fabrication deal from ExpressPCB limits the size of a double layer PCB to 3.8"x2.5", at time of design. I managed to design the layout of the PC-side PCB that contains only the transceiver circuitry to have a size of about 1.2"x1.2". The camera-side PCB that has both the transceiver and camera circuitries occupies a board area of about 3.8"x1.2". Therefore, I could fit 2 PC-side PCB and 1 camera-side PCB on a single 3.8"x2.5" PCB with plenty of space between them. The individual PCBs are meant to be cut out from the bigger piece of PCB as shown in Figure 6 and Figure 7.

2.1.7.1 Top layer

All components, except for the crystal for the RF transceiver circuitry and a capacitor, are on the top layer. Traces connected to the bypass capacitors are made as short as possible. To minimize signal reflections caused by impedance mismatch, traces from the RF transceiver to the balun, and from the balun to the antenna are designed to be symmetric. Besides that, the traces connecting the RF output pins to the balun have an impedance of 100Ω which is achieved by having trace width of about 0.030 inches for the given material. [http://circuitcalculator.com/wordpress/2006/01/24/trace-resistance-calculator/] The trace between the antenna and the output of the balun is designed to have impedance of 50Ω, which is achieved by having trace width of about 0.1 inches for the given material. Traces with high frequency signals such as clock signals are kept away from other signals to prevent coupling of the high frequency signals into the quieter signals.

2.1.7.2 Bottom layer

The bottom layer consists of the ground plane, signal routing, RF transceiver circuitry crystal and a capacitor. The ground plane is carefully shaped so that the RF ground plane, analog ground plane and the digital ground plane meet only at the star point of the RF transceiver chip as advised by the AT86RF230 datasheet. To prevent the crystal from introducing noise to the ground planes, a cutout of the ground plane is placed around the crystal.

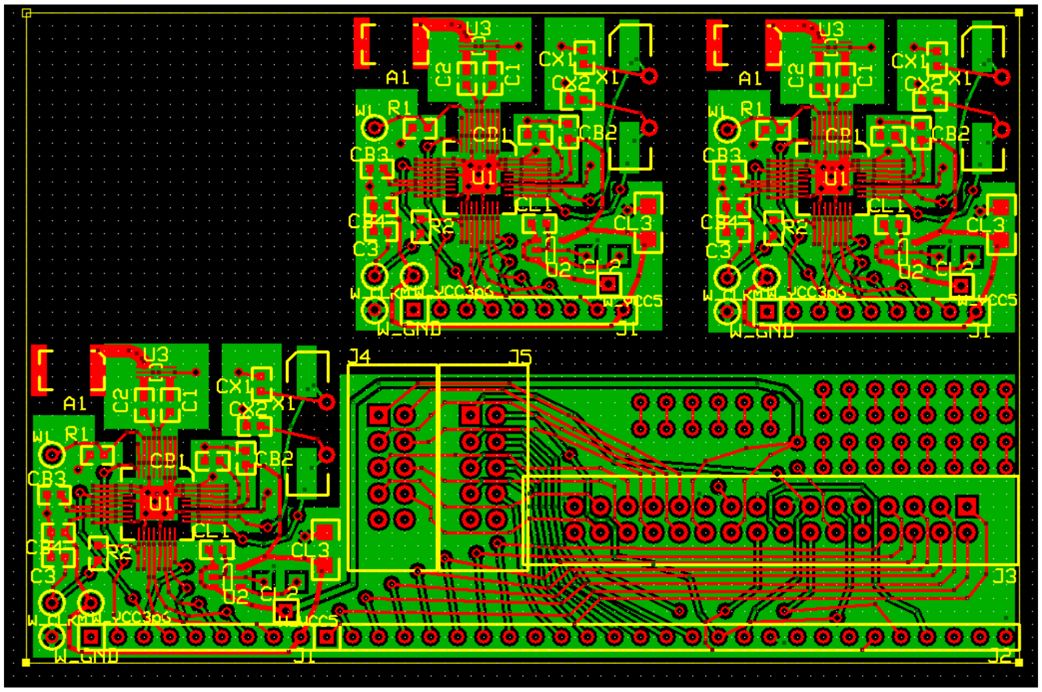


Figure 5 - PCB layout

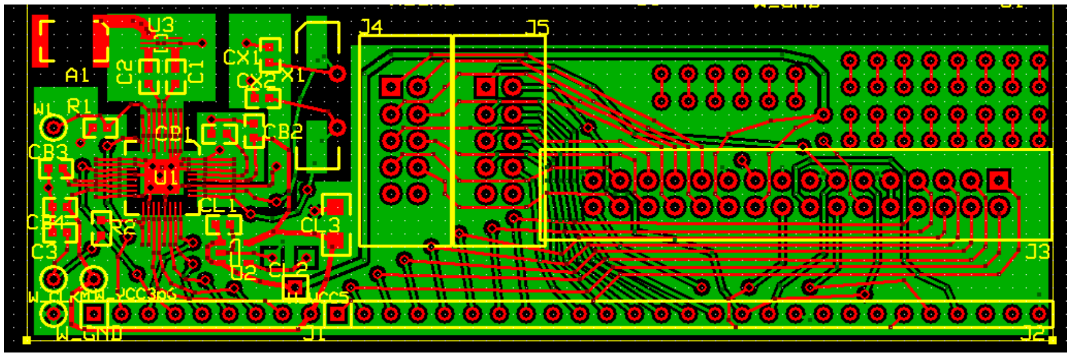


Figure 6 - PCB cutout for camera-side board

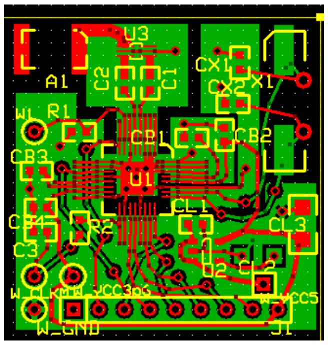


Figure 7 - PCB cutout for PC-side board

2.1.8 Assembled system

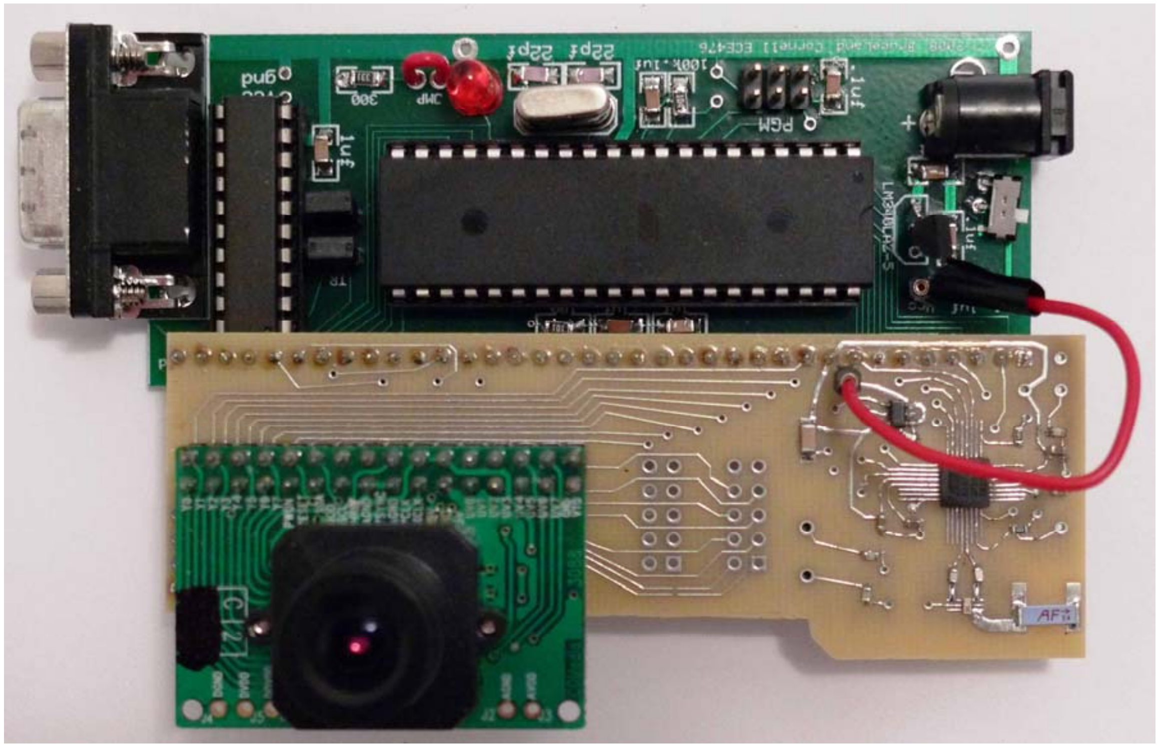


Figure 8 - Camera-side subsystem

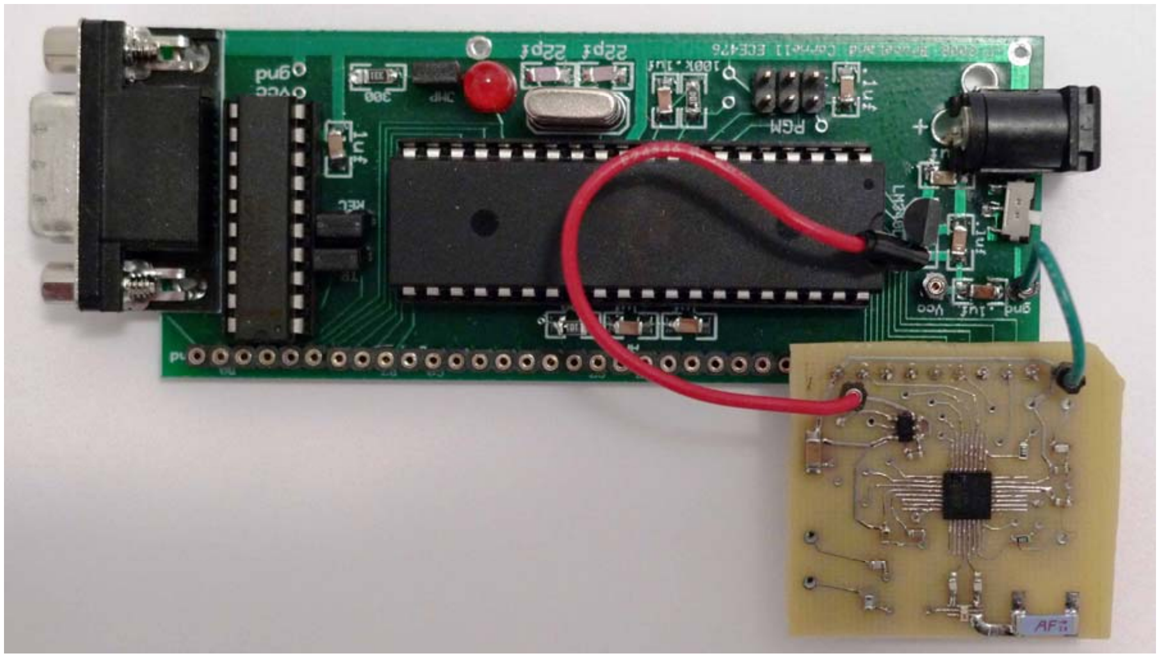


Figure 9 - PC-side subsystem

2.2 Embedded software architecture

2.2.1 Overview

The software architecture of the project consists of the embedded software architecture and the host software architecture. The embedded software architecture consists of the PC-side and the camera-side embedded software architecture.

The PC-side embedded subsystem sends a command to the camera-side subsystem to request for data. This command activates the camera and initiates the broadcast of image data via RF. When the video data is received by the PC-side embedded subsystem, it transmits it to the PC Java host software to be processed. The cycle is repeated for the next image stream.

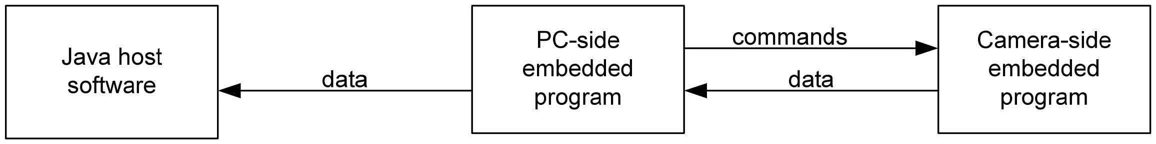


Figure 10 - Software architecture top level diagram

2.2.2 PC-side embedded software

The PC-side embedded program (*radiopc.c*) controls the camera-side program. With a video refresh rate of 32 seconds, the PC-side embedded program runs a microcontroller timer that creates interrupts to give the *start* command every 36 seconds. The time period of 36 seconds is chosen because of ease of implementation with just a timer that creates an interrupt every 4 seconds and a modulo-9 counter. In the COMMAND state, the RF transceiver is set to transmit mode and issues a command *activate* via RF to the camera-side receiver. The *activate* command is set as 0xA5. Then, the RF transceiver is set to receive mode to listen to incoming data from the camera-side. When received, the data is downloaded from the RF transceiver to the microcontroller via SPI and sent to the Java host software immediately via UART.

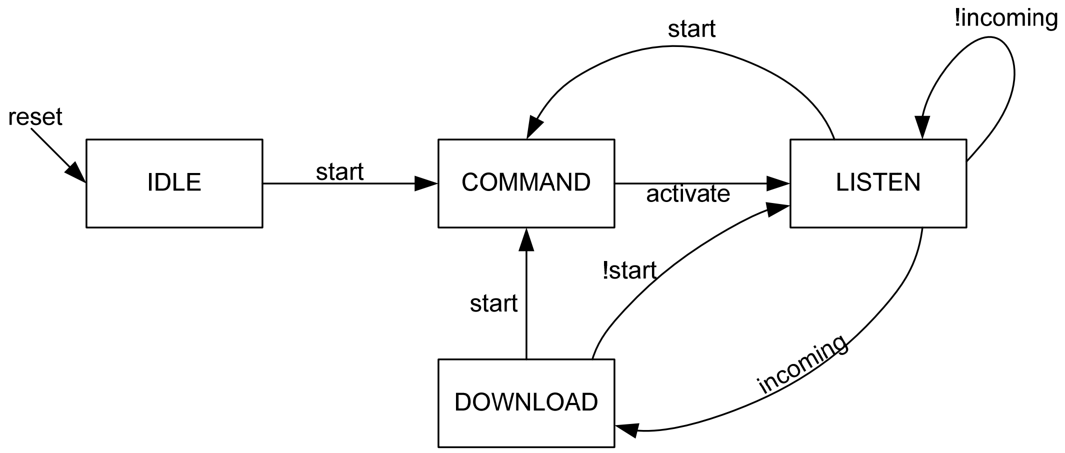


Figure 11 - PC-side embedded state machine

2.2.3 Camera-side embedded software

When the camera-side embedded program (*radiocam.c*) runs, the RF transceiver is set to receive mode to listen for the *activate* command from the PC-side. When the *activate* command is received, the RF transceiver is set to transmit mode to transmit the start preamble and the bitmap header, info header and color table. The start preamble has a size of 4 bytes and is set as the size of the bitmap file. Section 2.2.7 describes the bitmap format more thoroughly. Next, the camera captures a subframe of image data and transmits it via RF to the PC-side and this process repeats itself until the entire frame of image data is captured and transmitted. A frame of bitmap image consists of 47616 bytes (248x192) of data or 24 subframes (8 lines per subframe) which will be discussed in more detail in Section 2.2.6

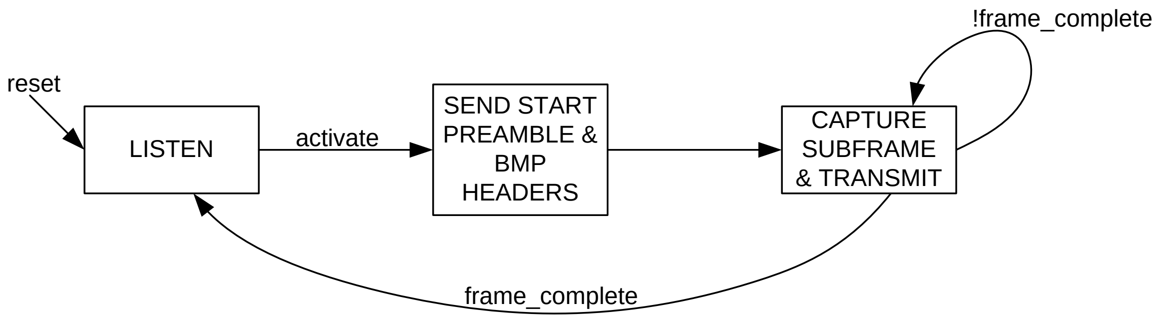

!frame_complete
reset
LISTEN
activate
SEND START PREAMBLE & BMP HEADERS
CAPTURE SUBFRAME & TRANSMIT
frame_complete

Figure 12 - Camera-side embedded state machine

2.2.4 RF communication

The project implements the Basic Operating Mode of the RF transceiver. The communication channel between the PC-side transceiver and the camera-side transceiver is RF. Both transceivers take turns to operate as a transmitter or a receiver at different moments in time for synchronization purposes.

The communication between the RF transmitter and the microcontroller is through SPI whereby the microcontroller is the SPI master and the RF transmitter the slave. To enable SPI communication, the microcontroller pulls the SPI /SEL pin low.

For RF transmission, the RF transceiver has to be first set to transmit mode with the *rfSetTxMode()* function which sets the transceiver in PLL_ON state as described in the AT86RF230 datasheet. Then the data to be transmitted is put into the transmit buffer (*txFrame*) with the data length specified in the *txDataLength* variable. Then the function *rfSendFrame()* is called to send the data over SPI from the microcontroller to the RF transceiver and packaged up for RF transmission. The data to be transmitted is packaged up into a frame made up of a byte for frame-transmit command (0x60), a byte for frame length and the data in the correct sequence. To transmit the frame of packaged data from the RF transceiver, the microcontroller pulls the SLP_TR pin on the RF transceiver high, which is taken care of by the function *rfSendFrame()* as well.

For RF reception, the RF transceiver has to be first set to receive mode with the *rfSetRxMode ()* function which sets the transceiver in RX_ON state as described in the AT86RF230 datasheet. Then the microcontroller can listen to incoming RF signals by checking the IRQ_STATUS register on the RF transceiver. The complete reception of a frame of data is indicated by the TRX_END bit of the IRQ_STATUS register. Next, the microcontroller can start retrieving data from the RF transceiver with the *rfRetrieveFrame()* function. The frame of data is retrieved through SPI a byte at a time whereby the microcontroller sends a byte of junk (arbitrary) data just to receive a byte of data from the RF transceiver. The frame of data is made up of a byte for frame-receive command (0x20), a byte for frame length, the data and a byte for LQI in the correct sequence. The LQI information can be used to determine the quality of transmission and the suspected integrity of the data received.

For data integrity checks, a header for RF frame transmission and reception is optionally implemented. The header is set to be 0x5A and is inserted between the frame length and the data in the *rfSendFrame()* function for transmission. Similarly, the *rfRetrieveFrame()* function would be modified to receive the header between the frame length and the data section in the frame.

2.2.5 UART communication

The project only requires UART transmit mode. The serial communication settings are chosen to have a baud rate of 38400 bps, 8 bits of data, 2 stop bits and no parity. When the PC-side embedded system receives data via RF, it immediately sends out the data via UART. The UART communication speed is the main bottle neck in transmission of data. Having a higher baud rate however increases transmission errors and this is caused by the MAX232 chip's series.

2.2.6 Video

The video stream consists of streaming bitmap images one after another. The C3088 camera uses a progressive scan read out of data. Important signals from the camera for the implementation of the project are VSYNC, HREF, PCLK and the Y bus. For the default settings, the VSYNC signal marks the start of the image scan when it goes from high to low; a high HREF signal provides a guide for each horizontal line of image scan whereby image data for that particular line is valid at the rising clock edge of PCLK. For an image of size 248x192, a naïve and simple method to capture an image involves sampling the data at the Y bus 248 times for each line (guided by each high HREF signal) by the microcontroller and then repeated for 192 lines when the VSYNC signal goes low.

However, to work with the limited size of the microcontroller memory (4KB for Atmega644P), the capturing process has to be modified unless external memory modules are added. Buffering of data is needed because of the inherent delay in transmitting the image data. By using only the amount of memory available in the microcontroller as an image buffer, three methods of capturing an image can be used – vertical capture, horizontal capture and box capture as shown in Figure 13. Each rectangle bounded by red lines in the figure represents an image data section that can be captured at any one time for the limited-size buffer and transmitted to the PC-side before the next rectangle can be captured. The vertical capture method is slow because for every horizontal scan, only one byte of data is taken. However, the camera can be set to run at a higher frequency without having to worry about missing camera sync signals because there will be plenty of time for the microcontroller to do processing. The image will not be over-exposed because higher camera system frequency results in shorter exposure time. The horizontal capture method is fast and simple to implement. However, the camera has to run at a lower frequency so that the microcontroller can keep up with the sync signals as more processing is performed between the sync signals. At a lower operation frequency, images tend to be over-exposed due to a longer minimum exposure time. The box capture method is fast but difficult to implement because of the complexity in merging the boxes to form a bigger image, either by merging individual box's bitmap data into a bigger image's bitmap data or displaying each box as separate bitmap image in the host software GUI. Considering all the tradeoffs above, I implemented the horizontal capture method for the project.

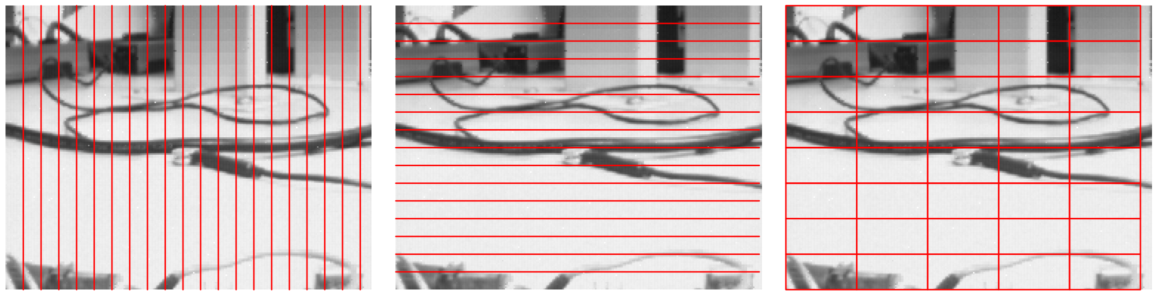


Figure 13 - Various methods for capturing image with limited buffer size. From left: Vertical capture, horizontal capture and box capture

The C3088 camera with the OV6620 image sensor has a default system clock frequency of 8.86MHz. Due to voltage constraints that affect the operation frequency, the microcontroller is run at 8MHz. For the microcontroller to be able to keep up with sampling the image data with the horizontal capture method and processing it, the camera system clock frequency has to be adjusted to run at 119.8 kHz.

Writing and reading data to and from the camera registers are done via SCCB (Serial Camera Control Bus) which is compatible with I^2C (Inter-Integrated Circuit) or TWI (Two Wire Interface). When writing to a camera register, the microcontroller sends the camera write ID (0xC0) which contains the write control bit '0' in its LSB bit, followed by the register address and then the data to be written. It is important to note that the OV6620 sensor takes its register read address from the previous write cycle. Therefore, when reading from a camera register, the microcontroller first performs a register write cycle that involves sending the camera write ID (0xC0), followed by the register read address. Next, the microcontroller sends the camera read ID (0xC1) which contains the read control bit '1' in its LSB bit before receiving the requested register data from the camera. A more detailed TWI usage description can be obtained from the Atmega644P and OV6620 datasheets.

2.2.7 Microsoft bitmap format

The image data obtained from the camera is made into bitmap format and then sent to the PC. Bitmap pictures are easily created by the microcontroller and easily converted into JPEG by the host software to be displayed on the PC. The bitmap format consists of four sections: Header, InfoHeader, ColorTable and RasterData. The following illustrates the bitmap format for a monochrome image of size 248x192 pixel[2]:

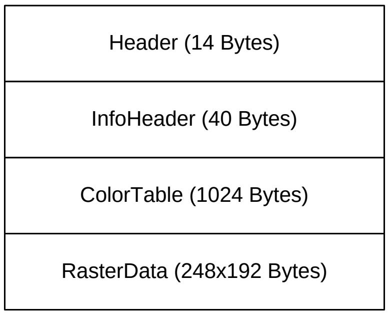


Figure 14 - Bitmap format

2.2.7.1 Header

The Header consists of 14 bytes of data in the following sequence: Signature (2 bytes), FileSize (4 bytes), Reserved (4 bytes) and DataOffset (4 bytes). The Signature section is by standard set to 'BM' or '424D' in hex. The FileSize section describes the total size of the bitmap file in bytes. The Reserved section is unused and set to 0. The DataOffset section describes starting location of RasterData in the file.

2.2.7.2 InfoHeader

InfoHeader consists of 40 bytes of data in the following sequence: size of InfoHeader (4 bytes) which is set to 40, width of bitmap (4 bytes), height of bitmap (4 bytes), number of planes (2 bytes) which is set to 1, Bitcount (2 bytes), types of compression (4 bytes) which is set to 0 for no compression, compressed size of image (4 bytes) which is set to 0 for no compression, horizontal resolution (4 bytes), vertical resolution (4 bytes), number of colors used (4 bytes) and number of important colors (4 bytes) which is set to 0 to denote all colors are important. The Bitcount section describes the number of bits to represent a pixel as follows:

Number of bits per pixel	Description
1	Monochrome palette, 1 color
4	4-bit palletized, 16 colors
8	8-bit palletized, 256 colors
16	16 bit RGB, 65536 colors
24	24 bit RGB, 1677216 colors

Table 2 - Bitcount section details

The horizontal and vertical resolution sections are denoted in number of pixels per meter.

2.2.7.3 ColorTable

The size of ColorTable section is directly affected by the number of colors used and is calculated by multiplying number of colors by 4. This is because every color needs to have specifications, in the following sequence, for red intensity (1 byte), green intensity

(1 byte) and blue intensity (1 byte) and reserved (1 byte). Therefore, for 256 colors (8 bits per pixel configuration) in our case, the size of the ColorTable section is 4x256=1024 bytes with the intensity of each color adjusted accordingly.

2.2.7.4 RasterData

RasterData contains raw data from the camera. Since image compression is not used, the size of this section is equivalent to the size of the image itself.

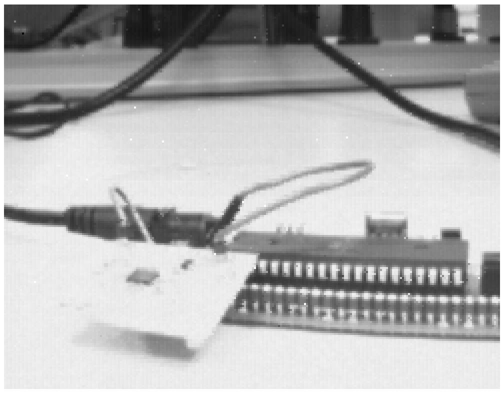


Figure 15 - One frame captured by the camera

2.3 Host software architecture

The host software is programmed in Java. The host software is capable of displaying streams of images on its display panel, recording, playing back or deleting any recordings selected by the user. It receives incoming data from the PC-side embedded system via UART and analyzes it. When a full frame of image is received, it updates the display panel with the latest image and if the recording function is enabled, it stores a copy of the image in local memory. The application organizes a main thread which executes from program start up and two minor threads that handle auto-reconnect of serial connection and recording playback respectively.

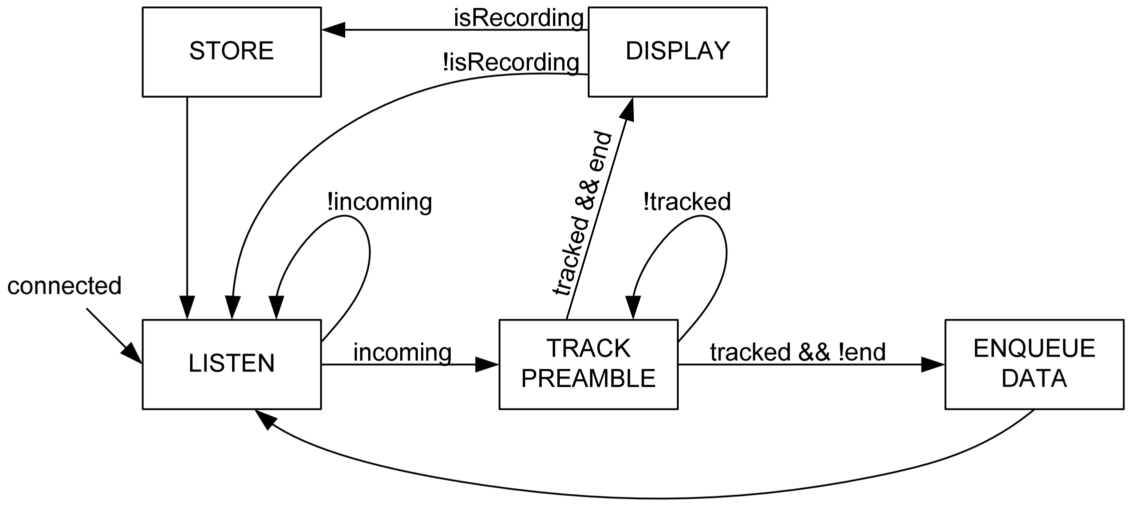


Figure 16 - Host software state machine for main thread

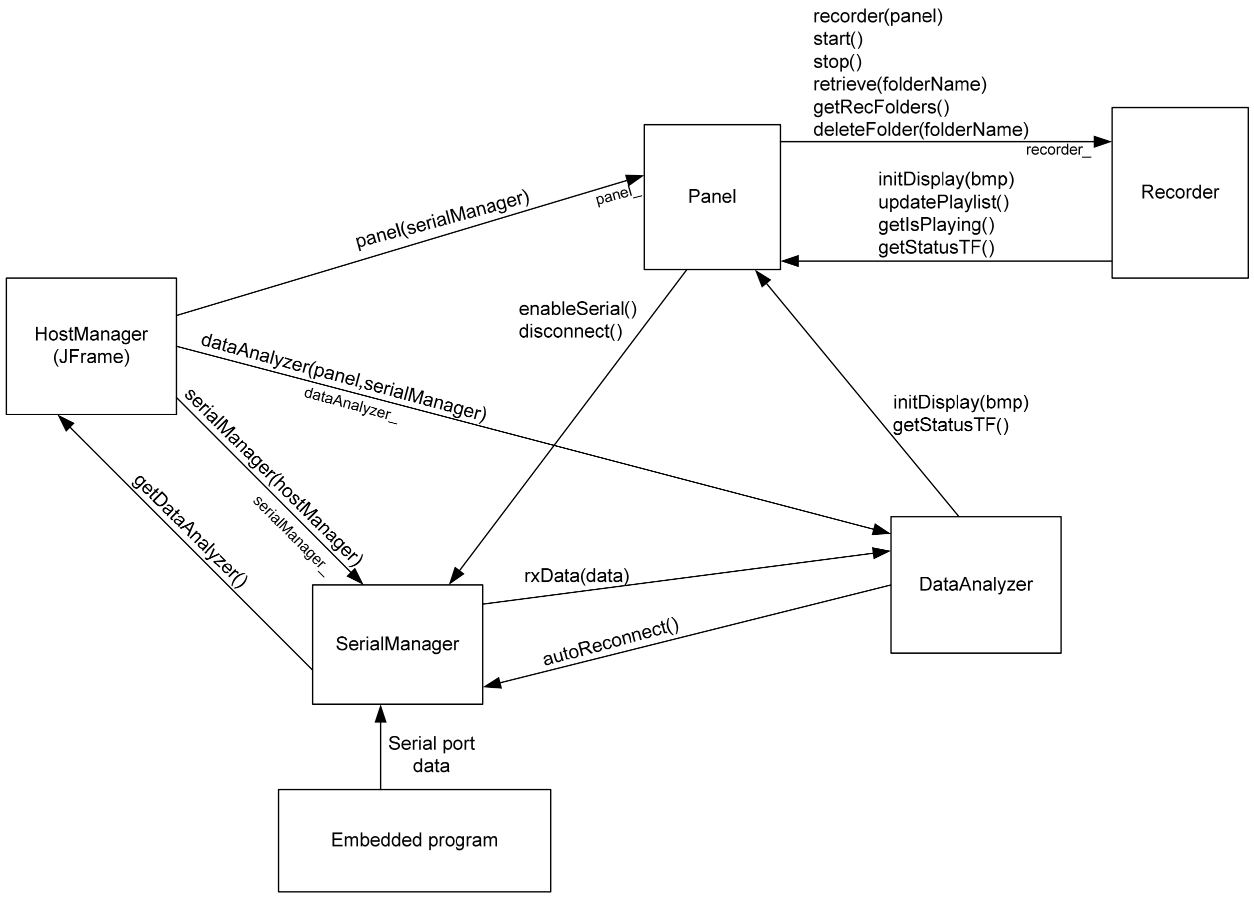


Figure 17 - Host software UML diagram

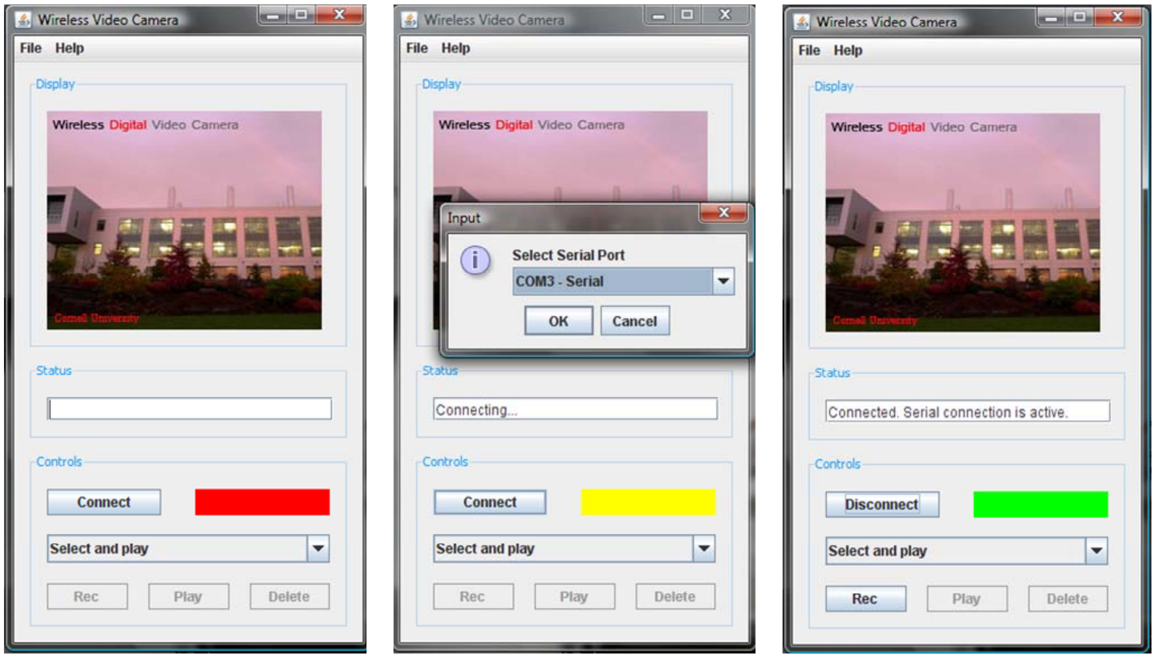
2.3.1 HostManager

The HostManager class is the main class where the host software starts executing from. It extends Java's JFrame class. It creates instances of SerialManager, Panel and DataAnalyzer classes in the correct sequence and passes on the instances to other classes that need them. At start up, an instance of SerialManager (defined as *serialManager_*) is created first followed by an instance of Panel (defined as *panel_*) which receives the said SerialManager instance. Next, an instance of DataAnalyzer (defined as *dataAnalyzer_*) which receives the said SerialManager and Panel instances is created. The GUI classes are then linked together in a network as shown in Figure 17.

Besides that, as an extension to JFrame, the HostManager class works as a platform to hold the Panel class, which is the main graphical user interface of the software.

2.3.2 SerialManager

The SerialManager class handles all the serial communication functions of the software. It uses the open source RXTX API to handle all low level serial communication with the computer. A call to the *enableSerial()* function searches for available serial ports and displays a message window that requests for user selection of a serial port. SerialManager then attempts to connect to the selected serial port. The status of the serial connection is updated accordingly on the Panel as shown in Figure 18. A red connection status bar indicates a no connection; yellow indicates connection in progress; green indicates a successful connection.



Connecting...

Connected. Serial connection is active.

Figure 18 - Serial connection status

When data is received, the SerialManager sends the data to DataAnalyzer using the function *rxData(data)*. An important function in the SerialManager class is the *autoReconnect()* function. Some data can be stuck in the serial engine or go missing if not flushed out. I realized that disconnecting and then re-connecting the serial communication solves this problem. Therefore, I implemented the *autoReconnect()* function to replace a manual disconnect and reconnect. This function disconnects the current serial connection and reconnects it with the previously selected serial port. However, it requires a separate thread to execute because disconnecting the serial connection from the current thread and reconnecting it hangs the thread.

2.3.3 DataAnalyzer

The DataAnalyzer class analyzes the data received from the SerialManager using the private function *detectPreamble()*. The start preamble for the image data frame sent from the camera-side embedded program is '0x00, 0x00, 0xbe, 0x36' in hex. The end preamble that marks the end of the image data frame is '0xaa, 0x55, 0xa5, 0x5a'. The *detectPreamble()* function tracks the data stream to find the start preamble, incrementing the *preambleByteCount_* variable by one with every matched preamble byte. Once all four bytes of the start preamble are detected, the *preambleByteCount_* variable should have a value of 4 and we know that any subsequent data is the image data. As long as the end preamble has not been detected yet, DataAnalyzer puts all incoming data into a queue. When the end preamble is detected, the *preambleByteCount_* variable would have been incremented up to 8 with all four matched end preamble bytes. At this point, we would have all image data in the queue. A quick check of the queue size allows DataAnalyzer to verify if the image data is valid. A successful check of the queue size enables DataAnalyzer to extract the data from the queue to create a bitmap file to be sent to Panel for display with the function *initDisplay(bitmap file)*.

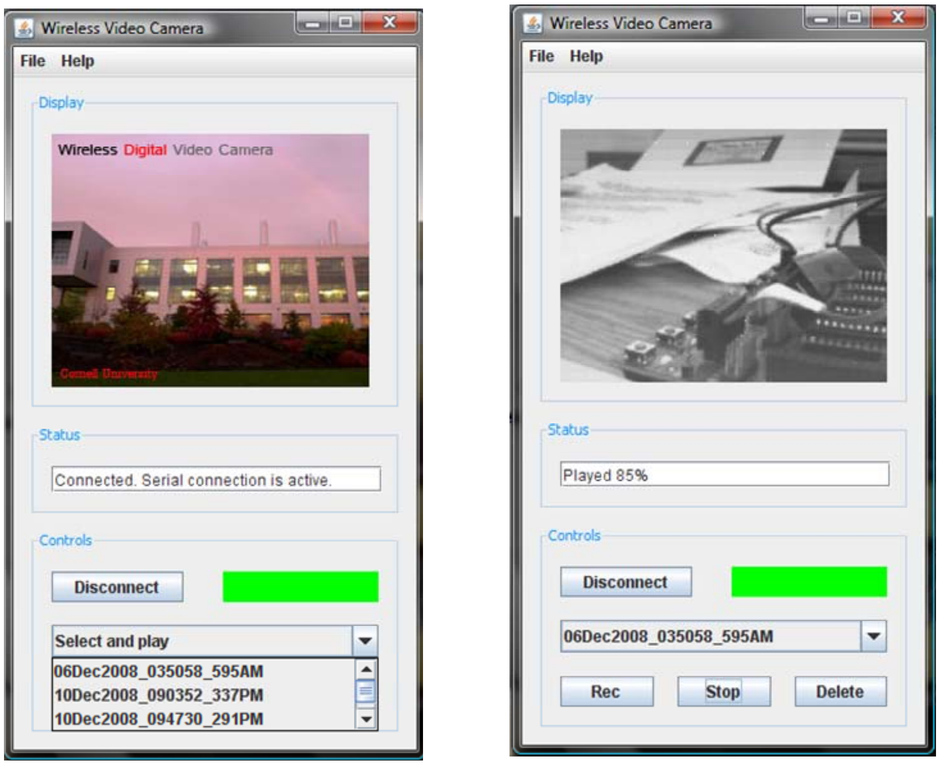
The DataAnalyzer is designed to handle non-ideal situations. Missing image data frames would not cause an error in processing the image file because of a image data queue size check mentioned above. Corrupted image data that still has the correct size is beyond the host software's control but is handled by the PC-side embedded program. Besides that, errors in the serial communication, especially those involving missing start or end preambles will hamper DataAnalyzer's algorithm. The variable *trackLatch_* is used to detect this problem. When *preambleByteCount_* is stuck at 0 for a long period of time indicating errors in the serial communication, DataAnalyzer will call the *autoReconnect()* function to fix the problem.

2.3.4 Panel

The Panel class is the main graphical user interface of the host software. It houses three subpanels – Display, Status and Controls. The Display subpanel contains the video display which is set on a JLabel; the Status subpanel displays the status of the program from serial connection status to recording, playing, stopping, deleting and auto-reconnect status; the Controls subpanel allows users to connect and disconnect the serial communication, record video and select from a list of recorded videos for playback or deletion.

The Panel class updates its video display using the *initDisplay(bitmap File)* function. The function is also responsible for storing the bitmap file into local memory if recording is enabled. This function is first called by the Panel class itself when initialized to display a start up screen. Subsequent calls to this function are either made by the DataAnalyzer when valid image data is completely received or by the Recorder when playback is in use. The function reads in a bitmap file and creates a JPEG file from it using Java's ImageIO class. It is important to use *ImageIO.read()* function to read in the JPEG file when updating the JLabel (ie, call *setIcon(ImageIO.read(jpeg file))*) because *ImageIO.read()* does no caching and immediately outputs the file when *setIcon* function needs it. If we call *setIcon(jpeg file)* instead, without using the *ImageIO.read()* function, the setIcon function fails to update even with JLabel's *repaint()*, *validate()* or *revalidate()* calls.

The playback feature needs to be executed on a separate thread from the current GUI thread that just fired the playback event. The current GUI thread freezes when it is used to retrieve the image file from local memory, reinitialize the JLablel and then repeat the process until the end of the recording. None of JLabel's *repaint(), validate()* or *revalidate()* built-in functions can solve the problem. Refer to *Panel.java* code in the Appendix section for implementation details.



Connected. Serial connection is active.

06Dec2008_035058_595AM
10Dec2008_090352_337PM
10Dec2008_094730_291PM

Played 85%

06Dec2008_035058_595AM

Figure 19 - Playback selection and execution

2.3.5 Recorder

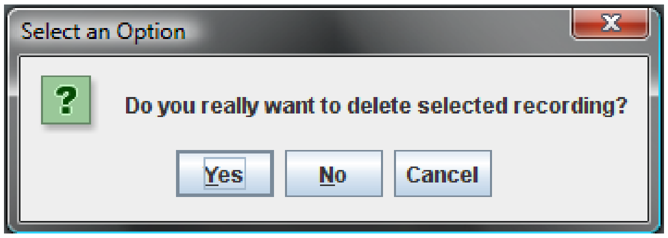
The Recorder class handles all functions involving storing and retrieving recordings to and from local memory. When the "Rec" button on the GUI is clicked, Panel calls the *start()* function in Recorder to enable recording. This involves creating a folder in local memory to store all valid image files collected while recording is enabled. The folder's naming convention is chosen to easily distinguish between recordings. It uses the Java's SimpleDateFormat which I define its format to be "ddMMMyyyy_hhmmss_SSSa", whereby "dd" is the day of the month in 2 digits, "MMM" is the name of the month spelled with 3 letters, "yyyy" is the year in 4 digits, "hhmmss" is the hour, minute and second in the standard 12-hour notation, "SSS" is millisecond and "a" is either AM or PM. An example of a folder name is "10Dec2008_094730_291PM" which represents a recording that started at 9:47pm on 10 December 2008. The names of the recording folders are directly listed in the user-selectable drop down box on the GUI as shown in Figure 19.

Besides a uniquely identifiable recording folder named accordingly to the start time of the recording, each recorded image stored in the recording folder is uniquely identifiable as well, using a 13-digit computer system time in milliseconds (*System.currentTimeMillis()*) as its name when the image is recorded.

Recording is disabled when the "Stop" button on the GUI is clicked and Recorder calls *updatePlaylist()* to update the list of recordings on the GUI.

The Recorder class is also responsible for retrieving recordings and displaying them during playback. The *retrieve(folder name)* function is called by Panel when the "Play" button on the GUI is clicked. This function retrieves all recorded images in the specified folder and displays them in sequence in a new thread as long as playback is still enabled. Once the "Stop" button is clicked, the function breaks, returns and stops playback.

The heart of the recording deletion is also handled by Recorder. When the "Delete" button on the GUI is clicked, with a recording selected from the GUI's playlist, a deletion confirmation message is displayed requesting for user confirmation as shown in Figure 20. When user confirmation is obtained, Panel calls Recorder's *deleteFolder(folder name)* function and the folder together with its content is deleted recursively.



Do you really want to delete selected recording?

Figure 20 - Delete confirmation request

3 Appendix

3.1 User manual

3.1.1 Components

3.1.1.1 Hardware

- PC-side unit
- Camera-side unit
- 1 Serial cable
- 2 DC-9V wall wart

3.1.1.2 Software

- Wireless Digital Video Camera JAR executable file (WiDiVCam.jar)
- RXTX plug-ins

3.1.2 Set up

3.1.2.1 Hardware

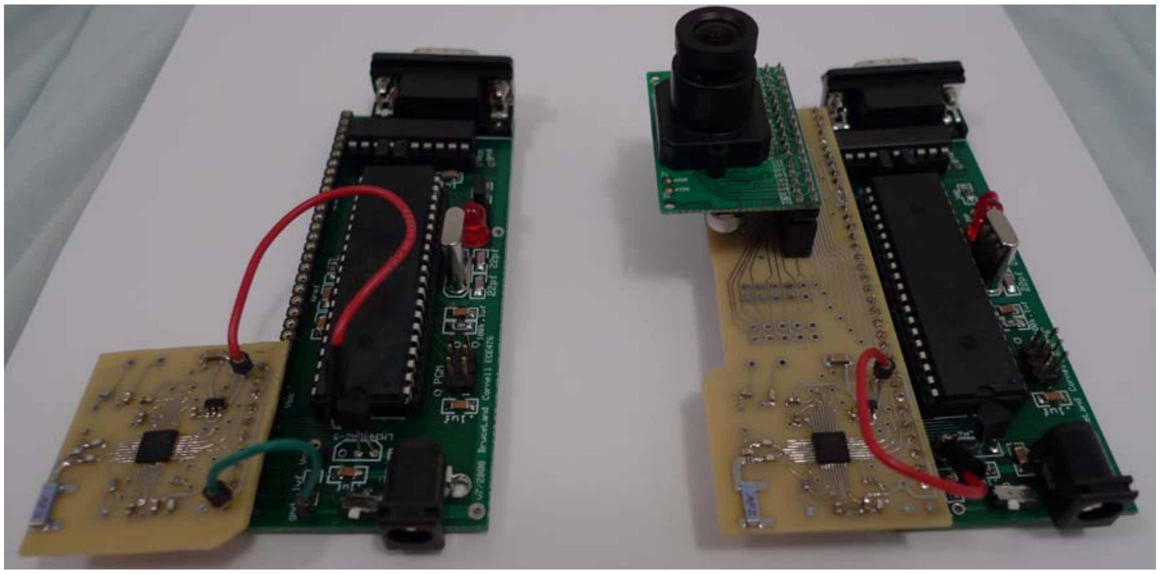


Figure 21 - Left: PC-side system. Right: camera-side system

- Connect the power sockets on the PC-side system and the camera-side system to the DC wall wart.
- Connect the serial port on the PC-side system to the serial port on the PC with the serial cable.
- Point camera to location of interest.
- Turn on power for both systems.

3.1.2.2 Software

- Install and set up the RXTX plug-ins for your computer's Java system according to the instructions given at www.rxtx.org.
- Double click on the WiDiVCam.jar file to execute the GUI. The program starts up as shown below:

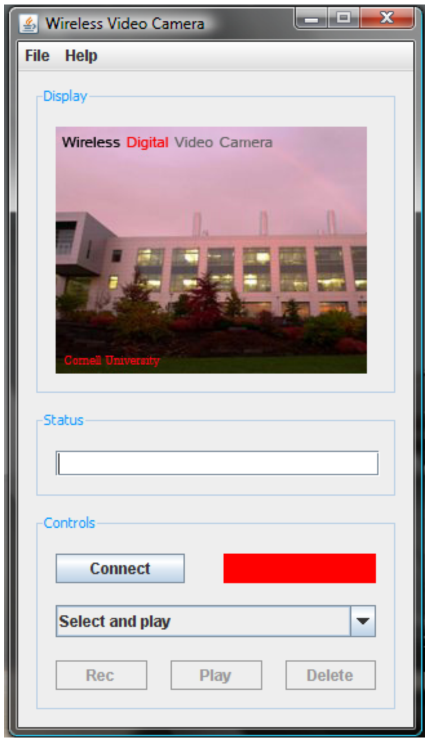


Figure 22 - GUI at start up

3.1.3 Video stream

- To start video stream, click the "Connect" button and the select from a pop-up window the COM Port to which the PC-side hardware system is connected as shown in Figure 18.
- The connection status bar turns green upon successful connection and the video will start streaming once the program locks onto the camera data stream.

3.1.4 Recording

- Recording is only enabled when serial connection is active. Otherwise, the "Rec" button is disabled.
- Click the "Rec" button to start recording and the button changes to "Stop". Recordings are automatically saved in local memory.
- To stop recording, click the "Stop" button.

3.1.5 Playback

- Playback is only enabled when a recording is selected from the drop-down playlist box that displays the text “Select and play”.
- Once a recording is selected, click the “Play” button to start playback. The “Play” button changes to “Stop”.
- To stop playback, click the “Stop” button.

3.1.6 Deletion

- Deletion of recording is only enabled when a recording is selected from the drop-down playlist box.
- Once a recording is selected, click the “Delete” button to delete the selected recording.
- A window pops up requesting for deletion confirmation. Click the “Yes” button to continue with deletion.

3.2 Project budget allocation

Expenses	**Cost ($)**
C3088 camera	46.50
MCU	Sampled
RF transceivers	Sampled
Cables	5
PCB (1 of 3 used)	60/3 = 20
Other components	10
Total	**81.50**

Table 3 - Budget allocation

3.3 Code

3.3.1 Embedded - CodeVision

3.3.1.1 radiopc.c

```
//radiopc.c     //pc side radio

#include <mega644.h>
#include <rf.h>
#include <stdio.h>
#include <string.h>

#define TRUE   1
#define FALSE  0
#define TIMEOUT 9      //time to loop back for next photo

unsigned char timer;

void initialize(void);
void initUART(void);
void fetch(void);

interrupt [TIM1_COMPA] void timer1_comp(void)  {
        if(timer>0) --timer;
}

void initialize(void){
        initSPI();              //set up SPI for MCU
        initTransceiver();      //set up transceiver
        initUART();

        DDRD.2 = 1;     //led indicator
        PORTD.2 = 0;

        TCCR1A = 0b00000000;  //Clear timer on compare match, coupled with TCCR0B settings
        TCCR1B = 0b00001101;  //Clear timer on compare match, Timer set up to f/1024
        OCR1AH = 0x7A; //produce timer for 4s, need to count to 31250=0x7A12, 9 of this yields 36s
        OCR1AL = 0x12;
        TIMSK1 = 0b00000010;    //interrupt enable for compare match A

        #asm
        sei     //enable interrupts
        #endasm
}

void initUART(void){
        UBRR0L = 12; // baud rate: 38400 for 8 MHz
        UCSR0B = (1<<4)|(1<<3); //enable receiver and transmit
        UCSR0C = (1<<7)|(1<<3)|(1<<2)|(1<<1);    //register select; 2 stop bits; 8 bits
}

void fetch(void){
        timer = TIMEOUT;        //reset timer
        rfSetTxMode();
        txDataLength = 1;
        txFrame[0] = ACT;
        rfSendFrame();

        rfSetRxMode();           //transceiver set to receive
        clearIRQ();

        while(timer>0){
                if(rfRxListenNoWait()==1){
                        PORTD.2 = ~PORTD.2;
                        rfRetrieveFrame();   //retrieve frame
                }
        }
}

void main(void){
        initialize();
        delay_ms(5000); //initial one-time delay
        while(1){
                if(timer==0)fetch();
        }
}
```

3.3.1.2 radiocam.c

```
//radiocam.c    //camera side radio and cam
#include <mega644.h>
#include <rf.h>
#include <stdio.h>
#include <twi.h>

//RF transmission frame constants
#define RF_FRAME_LIMIT                  128
#define PIC_WIDTH                       248
#define PIC_HEIGHT                      192     //pic height - divisible by NUM_ROWS_PER_FRAME
#define NUM_ROWS_PER_FRAME              8
#define LOG_NRPF                        3       //log2 of NUM_ROWS_PER_FRAME
#define LENGTH_FR                       1984    //Length of rectangle frame containing
NUM_ROWS_PER_FRAME x WIDTH
#define NUM_RECT_FOR_HEIGHT             24      //HEIGHT/NUM_ROWS_PER_FRAME
#define NUM_64B_IN_FRAME                31      //LENGTH_FR/64
#define NUM_PER_SEND                    64      //number of bytes sent in one subframe while
clearing sram buffer
#define LOG_NPS                         6       //log2 of NUM_PER_SEND

//twi/camera constants
#define CPU_FREQUENCY_HZ               8000000
#define TWI_PULLUP_RESISTOR_ENABLE    TRUE
#define TWI_CAMERA_WRITE_ADDRESS      0xC0
#define TWI_CAMERA_READ_ADDRESS       0xC1
#define TWI_DATA_BUFFER_LENGTH        1
#define CAM_HREF                      PIND.3
#define CAM_VSYNC                     PIND.2
#define CAM_PCLK                      PIND.4
#define TRUE                            1
#define FALSE                           0

//global
unsigned char twiDataBuffer[TWI_DATA_BUFFER_LENGTH];
unsigned char buff[LENGTH_FR]; //declare huge arrays first memory allocation

//functions
void initialize(void);
void initUART(void);
void resetCam(void);
void writeCam(unsigned int reg, unsigned char value);
unsigned char readCam(unsigned int reg);
void sendBmpHeader(unsigned int height, unsigned int width);
void sendBmpInfoheader(unsigned int height, unsigned int width);
void sendBmpTable(void);
void sendStartPreamble(void);
void sendEndPreamble(void);
void actCapture(void);

void initialize(void){
        initSPI();     //set up SPI for MCU
        initTransceiver();      //set up transceiver
        rfSetTxMode();
        initUART();     //initialize UART
        DDRD.2 = 1;     //LED indicator
        PORTD.2 = 0;

        #asm
        sei             //enable interrupts
        #endasm
}

//initialize UART
void initUART(void){
        UBRR0L = 12;    //baud rate: 38400 for 8MHz
        UCSR0B = (1<<4)|(1<<3); //enable receiver and transmit
        UCSR0C = (1<<7)|(1<<3)|(1<<2)|(1<<1);    //register select; 2 stop bits; 8 bits
}

//reset camera
void resetCam(void){
        twiReadRegister(TWI_CAMERA_WRITE_ADDRESS, TWI_CAMERA_READ_ADDRESS, 0x12, 1, twiDataBuffer);
        twiDataBuffer[0] |= 0b10000000;
        twiWriteRegister(TWI_CAMERA_WRITE_ADDRESS, 0x12, 1, twiDataBuffer);
}

//write to camera register
void writeCam(unsigned int reg, unsigned char value){
        twiDataBuffer[0] = value;
        twiWriteRegister(TWI_CAMERA_WRITE_ADDRESS, reg, 1, twiDataBuffer);
}

//read from camera register
unsigned char readCam(unsigned int reg) {
        twiReadRegister(TWI_CAMERA_WRITE_ADDRESS, TWI_CAMERA_READ_ADDRESS, reg, 1, twiDataBuffer);
        return twiDataBuffer[0];
}

//create and send header
void sendBmpHeader(unsigned int height, unsigned int width){
        unsigned char bytelow;
        unsigned char bytehigh;
        unsigned int sizefile = (unsigned int) (1078 + (height*width));
        bytelow = (sizefile << 8) >> 8;
        bytehigh = sizefile >> 8;

        //2 Bytes - BM bitmap signature
        txFrame[0] = 'B';
        txFrame[1] = 'M';
        //4 Bytes - Filesize = 14 + 40 +1024 + HEIGHT * WIDTH
        txFrame[2] = bytelow;
        txFrame[3] = bytehigh;
        txFrame[4] = 0;
        txFrame[5] = 0;
        //4 Bytes of reserved (= 0)
        txFrame[6] = 0;
        txFrame[7] = 0;
        txFrame[8] = 0;
        txFrame[9] = 0;
        //4 Bytes of offset for location of raster data
        txFrame[10] = 0x36;
        txFrame[11] = 0x04;
        txFrame[12] = 0;
        txFrame[13] = 0;

        txDataLength = 14;
        rfSetTxMode();
        rfSendFrame();
}

//create and send infoheader
void sendBmpInfoheader(unsigned int height, unsigned int width){
        unsigned char height_low;
        unsigned char height_high;
        unsigned char width_low;
        unsigned char width_high;

        height_low = (height << 8) >> 8;
        height_high = height >> 8;
        width_low = (width << 8) >> 8;
        width_high = width >>8;

        //4 Bytes - InfoHeader size: 40
        txFrame[0] = 40;
        txFrame[1] = 0;
        txFrame[2] = 0;
        txFrame[3] = 0;
        //4 Bytes - width of the image in pixels
        txFrame[4] = width_low;
        txFrame[5] = width_high;
        txFrame[6] = 0;
        txFrame[7] = 0;
        //4 Bytes - height of the image in pixels
        txFrame[8] = height_low;
        txFrame[9] = height_high;
        txFrame[10] = 0;
        txFrame[11] = 0;
        //2 Bytes - Number of planes
        txFrame[12] = 1;
        txFrame[13] = 0;
        //2 Bytes bitcount = 8
        txFrame[14] = 8;
        txFrame[15] = 0;
        //4 bytes - type of compression = none
        txFrame[16] = 0;
        txFrame[17] = 0;
        txFrame[18] = 0;
        txFrame[19] = 0;
        //4 bytes - no compression
        txFrame[20] = 0;
        txFrame[21] = 0;
        txFrame[22] = 0;
        txFrame[23] = 0;
        //4 bytes - horizontal resolution
        txFrame[24] = 0;
        txFrame[25] = 0;
        txFrame[26] = 0;
        txFrame[27] = 0;
        //4 bytes - vertical resolution
        txFrame[28] = 0;
        txFrame[29] = 0;
        txFrame[30] = 0;
        txFrame[31] = 0;
        //4 bytes - num of colors used = 256
        txFrame[32] = 0;
        txFrame[33] = 1;
        txFrame[34] = 0;
        txFrame[35] = 0;
        //4 bytes - num of important colors = all
        txFrame[36] = 0;
        txFrame[37] = 0;
        txFrame[38] = 0;
        txFrame[39] = 0;

        txDataLength = 40;
        rfSetTxMode();
        rfSendFrame();
}

//send color table
void sendBmpTable(void){
        unsigned int i;
        for(i=0; i<256;i++){
                txFrame[0]=i;
                txFrame[1]=i;
                txFrame[2]=i;
                txFrame[3]=0;
                txDataLength = 4;
                rfSetTxMode();
                rfSendFrame();
                delay_us(30);
        }
}

//send start preamble
void sendStartPreamble(void){
        unsigned long size = (unsigned long) (14 + 40 + 1024 + (PIC_HEIGHT*PIC_WIDTH));
        txFrame[0] = size >> 24;
        txFrame[1] = (size << 8) >> 24;
        txFrame[2] = (size << 16) >> 24;
        txFrame[3] = (size << 24) >> 24;
        txDataLength = 4;
        rfSetTxMode();
        rfSendFrame();
}

//send end preamble and flusher
void sendEndPreamble(void){
        //first 4 bytes are end preamble
        txFrame[0] = 0xAA;
        txFrame[1] = 0x55;
        txFrame[2] = 0xA5;
        txFrame[3] = 0x5A;

        //next 4 bytes are used to flush java serial so end preamble wont get stuck
        txFrame[4] = 0x01;
        txFrame[5] = 0x02;
        txFrame[6] = 0x03;
        txFrame[7] = 0x04;

        txDataLength = 8;
        rfSetTxMode();
        rfSendFrame();
}

//capture photo and send
void actCapture(void){
        unsigned int hort;
        unsigned int vert;
        unsigned int vertFull;
        unsigned int bypass=0;
        unsigned int trackBypass=0;
        unsigned char wDiv2=PIC_WIDTH>>1;

        unsigned int count=0;
        unsigned char del=0;      //delay to clear before consider next frame
        unsigned int i, j;

        rfSetTxMode();
        for(vertFull=0; vertFull<NUM_RECT_FOR_HEIGHT; vertFull++){
                        bypass = vertFull<<LOG_NRPF;   //vertFull*NUM_ROWS_PER_FRAME
                for(del=0; del<1; del++){

                        while(!CAM_VSYNC);            //wait for next frame
                        while(CAM_VSYNC);

                        while(!CAM_HREF);
                        while(CAM_HREF);
                }

                for(trackBypass=0; trackBypass<bypass; trackBypass++){
                        while(!CAM_HREF);
                        while(CAM_HREF);
                }
                for(vert=0; vert<NUM_ROWS_PER_FRAME; vert++){
                        while(!CAM_HREF);
                        for(hort=0; hort<wDiv2; hort++){
                                while(!CAM_PCLK);
                                buff[count++]=PINA;
                                while(CAM_PCLK);
                                while(!CAM_PCLK);
                                buff[count++]=PINA;
                                while(CAM_PCLK);
                        }
                        while(CAM_HREF);

                }
                count=0;
                txDataLength = NUM_PER_SEND;
                for(i=0; i<NUM_64B_IN_FRAME; i++){
                        for(j=0; j<NUM_PER_SEND; j++){
                                txFrame[j]=buff[(i<<LOG_NPS) + j];   //i*64 + j
                        }
                        rfSendFrame();
                        delay_ms(15);
                }
        }
}

void main(void){
       initialize();
        printf("\r Wireless Video Camera Version 1.0\r");
       initTwiMaster(CPU_FREQUENCY_HZ, TWI_PULLUP_RESISTOR_ENABLE);
       DDRA = 0x00;            //defined as input - signal from camera
       DDRD = (DDRD & 0xE3);   //signals from camera
       delay_ms(1500);

        resetCam();
        delay_ms(2);
        writeCam(0x11, 0x25);  // slow down camera clock
        delay_ms(2);

       while(1){
                rfSetRxMode();
                rfRxListenAndWait();
                PORTD.2 = ~PORTD.2;     //LED indicator
                rfRetrieveFrame();
                printf("\rRx: %d \r", rxFrame[0]);

                if(rxFrame[0] == ACT){
                        rfSetTxMode();
                        delay_us(4000);          //delay for PC side to prepare for rx

                        sendStartPreamble();
                        printf("\rp\r");
                        delay_us(30);
                        sendBmpHeader(PIC_HEIGHT,PIC_WIDTH);
                        printf("\rh\r");
                        delay_us(100);

                        sendBmpInfoheader(PIC_HEIGHT,PIC_WIDTH);
                        delay_us(6000);
                        printf("\ri\r");

                        sendBmpTable();
                        printf("\rt\r");

                        #asm("cli");
                        actCapture();
                        #asm("sei");
                        sendEndPreamble();
                        resetCam();
                        delay_ms(2);
                        writeCam(0x11, 0x25);
                        delay_ms(2);
                        rxFrame[0] = 0;
                }
          }
}
```

3.3.1.3 rf.h

```
#include <stdio.h>
#include <mega644_uart_tx.h>
#include <delay.h>

//transceiver registers
#define TRX_STATUS       0x01
#define TRX_STATE        0x02
#define TRX_CTRL_0       0x03
#define IRQ_MASK         0x0E
#define IRQ_STATUS       0x0F

//states of transceiver
#define TX_START         0x02
#define FORCE_TRX_OFF    0x03
#define RX_ON            0x06
#define TRX_OFF          0x08
#define PLL_ON           0x09
#define RX_AACK_ON       0x22
#define TX_ARET_ON       0x25

//pins
#define DDR_MOSI              DDRB.5
#define DDR_MISO              DDRB.6
#define DDR_SCLK              DDRB.7
#define SEL                   PORTB.4
#define DDR_SEL               DDRB.4
#define IRQ                   PINB.2
#define DDR_IRQ               DDRB.2
#define SLP_TR                PORTB.3
#define DDR_SLP_TR            DDRB.3
#define RESET                 PORTB.1
#define DDR_RESET             DDRB.1

#define IRQ_TRX_END     0x08  //interrupt
#define ACT            0xA5   //From PC-side, to activate cam-side
#define HEADER_BYTE     0x5A         //Header for each frame transmission, receive checks for it

void initSPI(void);
void initTransceiver(void);
void rfSetRxMode(void);
void rfSetTxMode(void);
void rfSendFrame(void);
void rfRxListenAndWait(void);
unsigned char rfRxListenNoWait(void);
void rfRetrieveFrame(void);
void clearIRQ(void);
unsigned char rfReadRegister(unsigned char addr);
void rfWriteRegister(unsigned char addr, unsigned char data);
unsigned char RF_createChecksum(unsigned char *buff, unsigned char size);

unsigned char txFrame[64];            //tx buffer, to put data to be sent
unsigned char txDataLength;           //length of data to be sent
unsigned char rxFrame[64];            //rx buffer, can grab received data here
unsigned char rxDataLength;           //length of data to be received
unsigned char LQI;                    //can check quality of trx
unsigned char checkStatusIRQ;         //temp variable to check STATUS_IRQ
```

```
//initialize SPI settings
void initSPI(void){
        //set directions for MCU SPI ports
        DDR_MOSI = 1;
        DDR_MISO = 0;
        DDR_SCLK = 1;
        DDR_SEL = 1;
        SPCR0 = 0b01010000;    //enable SPI with MCU as master
        SPSR0 = 1;                     //double speed
}

//initialize transceiver settings, as receiver first
void initTransceiver(void){
        //set port directions
        DDR_IRQ = 0;
        DDR_SLP_TR = 1;
        DDR_RESET = 1;
        DDR_SEL = 1;

        //set signals
        SEL = 1;
        RESET = 1;
        SLP_TR = 0;

        RESET = 0;
         delay_us(1);
        RESET = 1;
        rfWriteRegister(TRX_CTRL_0,0b01001000);      //output current
        delay_us(800);
        rfWriteRegister(IRQ_MASK,0b00001000);        //TRX_END interrupt
        delay_us(200);
        rfWriteRegister(TRX_STATE,FORCE_TRX_OFF);
        delay_us(1880);
        rfWriteRegister(TRX_STATE,RX_ON); //init as rx
        delay_us(200);
}

//set transceiver in receive mode
void rfSetRxMode(void){
        rfWriteRegister(TRX_STATE,FORCE_TRX_OFF);
        delay_us(1880);
        rfWriteRegister(TRX_STATE,RX_ON);
        delay_us(200);
}

//set transceiver in transmit mode
void rfSetTxMode(void){
        rfWriteRegister(TRX_STATE,FORCE_TRX_OFF);
        delay_us(1880);
        rfWriteRegister(TRX_STATE,PLL_ON);
        delay_us(200);
}

//send out frame with txFrame and txDataLength filled
void rfSendFrame(void){ //send out frame
        unsigned char i;
        rfWriteRegister(TRX_STATE,PLL_ON);
        SEL = 0; //enable SPI transfer
        SPDR0 = 0b01100000; //frame tx command
        while((SPSR0&0x80) == 0); //wait till done
        SPDR0 = txDataLength;  //send frame length
        while((SPSR0&0x80) == 0); //wait till done
        for(i=0; i<txDataLength; i++){        //send out data
                SPDR0 = txFrame[i];
                while((SPSR0&0x80) == 0);  //wait till done
        }
        SEL = 1; //end SPI transfer

        SLP_TR = 1;    //release frame via RF
```

```
         delay_us(1);
        SLP_TR = 0;

        //make sure transmit is complete
        do {
                if (IRQ != 0)   checkStatusIRQ = rfReadRegister(IRQ_STATUS);
        } while ((checkStatusIRQ & IRQ_TRX_END) == 0);
        checkStatusIRQ = 0;
}

//listen and won't return until detected incoming data
void rfRxListenAndWait(void){
        do {
                if (IRQ != 0)   checkStatusIRQ = rfReadRegister(IRQ_STATUS);
        } while ((checkStatusIRQ & IRQ_TRX_END) == 0);
        checkStatusIRQ = 0;
}

//checks for incoming data then return boolean if any
unsigned char rfRxListenNoWait(void){
        unsigned received = 0;
        if (IRQ !=0) {
                checkStatusIRQ = rfReadRegister(IRQ_STATUS);
                if ((checkStatusIRQ & IRQ_TRX_END) != 0) received = 1;
                else received = 0;
        }
        checkStatusIRQ = 0;
        return received;
}

//retrieve frame of data
void rfRetrieveFrame(void){
        unsigned char i;
        unsigned char data;
        SEL = 0; //enable SPI transfer
        SPDR0 = 0b00100000; //frame receive command
        while ((SPSR0&0x80)==0);      //wait till done
        SPDR0 = 0xAA;  //arbitrary data to rx a byte
        while((SPSR0&0x80)==0);
        rxDataLength = SPDR0;  //receive rxDataLength
        for (i=0; i<rxDataLength; i++){
                SPDR0 = 0xAA;
                while ((SPSR0&0x80)==0);      //wait till done
                data = SPDR0;
                uart_send_byte(data);  //send to uart
                rxFrame[i] = data;
        }
        SPDR0 = 0xAA;
        while ((SPSR0&0x80)==0);      //wait till done
        LQI = SPDR0;
        //uart_send_byte(LQI);
        SEL = 1;       //end SPI transfer
}

//clear IRQ
void clearIRQ(void){
        checkStatusIRQ = rfReadRegister(IRQ_STATUS);
        checkStatusIRQ = 0;
}

//read transceiver's register given address
unsigned char rfReadRegister(unsigned char addr) {
        unsigned char temp;
        SEL = 0;       //enable spi transfer
        SPDR0 = 128 + (addr & 0b00111111); //6-bit address
        while((SPSR0&0x80) == 0); //Wait till done
        temp = SPDR0;
        SPDR0 = 0xAA;  //send arbitrary data to receive back register data
        while((SPSR0&0x80) == 0); //Wait till done
        SEL = 1;
        return SPDR0; //data read from register
}

//write transceiver's register given address and data to be written
void rfWriteRegister(unsigned char addr, unsigned char data) {
        unsigned char temp;
        SEL = 0;        //enable  spi transfer
        SPDR0 = 192 + (addr & 0b00111111);
        while((SPSR0&0x80) == 0);  //Wait till done
        temp = SPDR0;
        SPDR0 = data;
        while ((SPSR0&0x80) == 0);  //Wait till done
        SEL = 1;        //end spi transfer
}

//create simple checksum
unsigned char RF_createChecksum(unsigned char *buff, unsigned char size){ //see wikipedia checksum
    unsigned char i=0;
    unsigned char chks=0;
        while(i++<size){        //sum up data
                chks = chks + *buff++;
        }
        chks = chks&0xff;
        chks = ~chks + 1; //get 2's-complement: flip bits add 1
        printf("CHKS: %x \r", chks);
        return chks;
}
```

3.3.1.4 mega644_uart_tx.h

```
#define UDRE0 5

void uart_send_byte_array(unsigned char *data, unsigned int length);
void uart_send_byte(unsigned char data);

//send byte array with specified length
void uart_send_byte_array(unsigned char *data, unsigned int length) {
        unsigned int counter = 0;
        while (counter++ < length) {
                while ( !( UCSR0A & (1<<UDRE0)) );    // Wait for buffer
                UDR0 = *data++;                               // Send out data
        }
}

//send byte
void uart_send_byte(unsigned char data) {
        while ( !( UCSR0A & (1<<UDRE0)) );    // Wait buffer
        UDR0 = data;                          // Send out data
}
```

3.3.1.5 twi.h

```
//twi.h

#define TW_MAX_RETRY    5

//twi define
#define TWI_FREQUENCY_HZ              100000
#define TWI_READ                      1
#define TWI_WRITE                     0
#define TWI_GENERAL_ADDRESS           0
#define TWSR_MASK                     0xF8

//TWCR register constants
#define TWINT          0b10000000
#define TWEA           0b01000000
#define TWSTA          0b00100000
#define TWSTO          0b00010000
```

```
#define TWWC           0b00001000
#define TWEN           0b00000100
#define TWIE           0b00000001

//twi master tx status codes
#define TWI_MT_ADR_ACK               0x18   // SLA+W tramsmitted, ACK received
#define TWI_MT_ADR_NACK              0x20   // SLA+W tramsmitted, NACK received
#define TWI_MT_DATA_ACK              0x28   // Data byte tramsmitted, ACK received
#define TWI_MT_DATA_NACK             0x30   // Data byte tramsmitted, NACK received

//twi master rx status codes
#define TWI_MR_ADR_ACK               0x40   // SLA+R tramsmitted, ACK received
#define TWI_MR_ADR_NACK              0x48   // SLA+R transmitted, NACK received
#define TWI_MR_DATA_ACK              0x50   // Data byte received, ACK tramsmitted
#define TWI_MR_DATA_NACK             0x58   // Data byte received, NACK tramsmitted

//twi slave tx status codes
#define TWI_ST_ADR_ACK               0xA8   // Own SLA+R received, ACK returned
#define TWI_ST_ADR_ACK_M_ARB_LOST    0xB0   // Arb lost in SLA+R/W as Master, own SLA+R received,
ACK returned
#define TWI_ST_DATA_ACK              0xB8   // Data byte TWDR transmitted, ACK received
#define TWI_ST_DATA_NACK             0xC0   // Data byte TWDR transmitted, NACK received
#define TWI_ST_DATA_ACK_LAST_BYTE    0xC8   // Last data byte in TWDR transmitted, ACK received

//twi slave rx status codes
#define TWI_SR_ADR_ACK               0x60   // Own SLA+W received, ACK returned
#define TWI_SR_ADR_ACK_M_ARB_LOST    0x68   // Lost arb in SLA+R/W as Master, own SLA+W received,
ACK returned
#define TWI_SR_GEN_ACK               0x70   // General call addr received, ACK returned
#define TWI_SR_GEN_ACK_M_ARB_LOST    0x78   // Lost arb in SLA+R/W as Master, general call addr
received, ACK returned
#define TWI_SR_ADR_DATA_ACK          0x80   // Previously addressed with own SLA+W, data received,
ACK returned
#define TWI_SR_ADR_DATA_NACK         0x88   // Previously addressed with own SLA+W, data received,
NACK returned
#define TWI_SR_GEN_DATA_ACK          0x90   // Previously addressed with general call, data
received, ACK returned
#define TWI_SR_GEN_DATA_NACK         0x98   // Previously addressed with general call, data
received, NACK returned
#define TWI_SR_STOP_RESTART          0xA0   // STOP condition or repeated START condition received
as slave

//other status codes
#define TWI_START                    0x08   // START transmitted
#define TWI_REP_START                0x10   // Repeated START transmitted
#define TWI_ARB_LOST                 0x38   // Arbitration lost
#define TWI_NO_STATE                 0xF8   // No relevant state information
#define TWI_BUS_ERROR                0x00   // Bus error with illegal START/STOP conditions

//function return status
#define TWI_SUCCESS                  0
#define TWI_INVALID_STATUS_ERROR     1
#define TWI_NO_ACK_ERROR             2
#define TWI_INVALID_SLA_ERROR        3
#define TWI_ARB_LOST_ERROR           4
#define TWI_NO_DATA_ERROR            5

//initialize
void initTwiMaster(unsigned long cpu_freq, unsigned char pullup_resistor) {
	float temp;

	if (pullup_resistor) {
		DDRC.0 = 0;
		DDRC.1 = 0;
		PORTC.0 = 1;
		PORTC.1 = 1;
	}

	temp = (float) cpu_freq / (float) TWI_FREQUENCY_HZ;
```

```
        TWBR = (temp - 16) / 2 ;//TWI Bit Rate Register
                              //I2C Freq = CPU Freq / (16 + 2*TWBR*4^TWPS)

        TWSR = 0x00;          //prescaler 1
}

//send START, send SLA+W, send register address, send START, send SLA+R, grab data, STOP
unsigned char twiReadRegister(unsigned char slaveWriteAddress, unsigned char slaveReadAddress,
                              unsigned int regAddress, unsigned char length, unsigned char *data){
        unsigned char sla, i, n = 0;
        sla = slaveWriteAddress | (((regAddress >> 8) & 0x07) << 1);

        retry:
        if (n++ >= TW_MAX_RETRY)
                return TWI_NO_ACK_ERROR;
        begin:
        TWCR = TWINT | TWSTA | TWEN;  //START
        while (!(TWCR & TWINT));      //wait for tx (TWINT)
        switch (TWSR & TWSR_MASK) {   //check status
                case TWI_REP_START:
                case TWI_START:               //OK
                        break;
                case TWI_ARB_LOST:
                        goto begin;
                default:
                        return TWI_INVALID_STATUS_ERROR;
        }

        TWDR = sla | TWI_WRITE;               //send SLA+W
        TWCR = TWINT | TWEN;          //clear interrupt, start tx
        while (!(TWCR & TWINT));      //wait for tx (TWINT)
        switch (TWSR & TWSR_MASK) {   //check status
                case TWI_MT_ADR_ACK:  //OK
                        break;
                case TWI_MT_ADR_NACK: //NACK -> retry
                        goto retry;
                case TWI_ARB_LOST:
                        goto begin;
                default:              //error -> STOP
                        goto error;
        }

        TWDR = regAddress;            //send register address
        TWCR = TWINT | TWEN;          //clear interrupt, start tx
        while (!(TWCR & TWINT));      //wait for tx (TWINT)
        switch (TWSR & TWSR_MASK) {   //check status
                case TWI_MT_DATA_ACK: //OK -> break
                        break;
                case TWI_MT_DATA_NACK://NACK -> quit
                        goto quit;
                case TWI_ARB_LOST:
                        goto begin;
                default:              //error -> STOP
                        goto error;
        }

        //Stop/pause TWI interface
        TWCR = 0;
        delay_us(2);

        TWCR = TWINT | TWSTA | TWEN;  //send START
        while (!(TWCR & TWINT));      //wait for tx
        switch (TWSR & TWSR_MASK) {     //check status
                case TWI_START:
                case TWI_REP_START:
                        break;
                case TWI_ARB_LOST:
                        goto begin;
                default:
```

```
                goto error;
        }

        sla = slaveReadAddress |(((regAddress >> 8) & 0x07) << 1);

        TWDR = sla | TWI_READ;        //send SLA+R
        TWCR = TWINT | TWEN;          //clear interrupt, start tx
        while (!(TWCR & TWINT));      //wait for tx
        switch (TWSR & TWSR_MASK) {     //check status
                case TWI_MR_ADR_ACK:
                        break;
                case TWI_MR_ADR_NACK:
                        goto quit;
                case TWI_ARB_LOST:
                        goto begin;
                default:
                        goto error;
        }

        for (i = 0; i < length; i++) {  //get content of register
                if (i == (length-1)) TWCR = TWINT | TWEN;
                else TWCR = TWINT | TWEN | TWEA;
                while (!(TWCR & TWINT));
                switch (TWSR & TWSR_MASK) {
                        case TWI_MR_DATA_NACK:
                        case TWI_MR_DATA_ACK:
                                *data++ = TWDR;
                                break;
                        default:
                                goto error;
                }
        }

        TWCR = TWINT | TWSTO | TWEN;    //STOP
        while(TWCR & TWSTO);
        return TWI_SUCCESS;             //return success status

        error:
        quit:
        TWCR = TWINT | TWSTO | TWEN;    //STOP
        while(TWCR & TWSTO);
        return TWI_INVALID_STATUS_ERROR;//return error status
}

//send START, send SLA+W, send register address, write data, STOP
unsigned char twiWriteRegister(unsigned char slaveWriteAddress, unsigned int regAddress,
                                        unsigned char length, unsigned char *data) {
        unsigned char sla, i, n = 0;
        sla = slaveWriteAddress |(((regAddress >> 8) & 0x07) << 1);

        retry:
        if (n++ >= TW_MAX_RETRY)
                return TWI_NO_ACK_ERROR;
        begin:
        TWCR = TWINT | TWSTA | TWEN;  //send START
        while (!(TWCR & TWINT));        //wait for tx (TWINT)
        switch (TWSR & TWSR_MASK) {     //check status
                case TWI_REP_START:
                case TWI_START:               //OK
                        break;
                case TWI_ARB_LOST:
                        goto begin;
                default:
                return TWI_INVALID_STATUS_ERROR;
        }

        TWDR = sla | TWI_WRITE;                //send SLA+W
        TWCR = TWINT | TWEN;           //clear interrupt, start tx
        while (!(TWCR & TWINT));        //wait for tx (TWINT)
        switch (TWSR & TWSR_MASK) {     //check status
                case TWI_MT_ADR_ACK:    //OK
                        break;
                case TWI_MT_ADR_NACK:   //NACK -> retry
                        goto retry;
                case TWI_ARB_LOST:
                        goto begin;
                default:                //error -> STOP
                        goto error;
        }

        TWDR = regAddress;              //send register address
        TWCR = TWINT | TWEN;            //clear interrupt, start tx
        while (!(TWCR & TWINT));        //wait for tx (TWINT)
        switch (TWSR & TWSR_MASK) {     //check status
                case TWI_MT_DATA_ACK:   //OK
                        break;
                case TWI_MT_DATA_NACK:  //NACK -> quit
                        goto quit;
                case TWI_ARB_LOST:
                        goto begin;
                default:                //error -> STOP
                        goto error;
        }

        for (i = 0; i < length; i++) {  //write data
                TWDR = *data++;
                TWCR = TWINT | TWEN;
                while (!(TWCR & TWINT));
                switch (TWSR & TWSR_MASK) {     //check status
                        case TWI_MT_DATA_ACK:   //OK
                                break;
                        case TWI_MT_DATA_NACK:  //write protected? -> quit
                                goto quit;
                case TWI_ARB_LOST:
                                goto begin;
                        default:                //error -> STOP
                                goto error;
                }
        }

        TWCR = TWINT | TWSTO | TWEN;    //STOP
        while(TWCR & TWSTO);
        return TWI_SUCCESS;

        error:
        quit:
        TWCR = TWINT | TWSTO | TWEN;    //STOP
        while(TWCR & TWSTO);
        return TWI_INVALID_SLA_ERROR;
}
```

3.3.2 Java

3.3.2.1 HostManager.java

```
package host;
import java.awt.event.ActionEvent;
import java.io.IOException;
import javax.comm.PortInUseException;
import javax.comm.UnsupportedCommOperationException;
import javax.swing.JFrame;
import javax.swing.JMenu;
import javax.swing.JMenuBar;
import javax.swing.JMenuItem;
import javax.swing.JOptionPane;
```

```
/**
 * HostManager class
 * Main
 * @author bentzx
 */
public class HostManager extends JFrame{
	private static final long serialVersionUID = 1L;
	private Panel panel_;			//Panel
	private DataAnalyzer dataAnalyzer_;		//DataAnaylzer
	private SerialManager serialManager_;	//SerialManager
	private JMenuItem helpMenuAbout_;
	private JMenuItem fileMenuExit_;
	private JMenu fileMenu_;
	private JMenu helpMenu_;
	private JMenuBar menuBar_;

	public static final String PROJECT_NAME = "Wireless Video Camera";

	/**
	 * HostManager constructor
	 * @throws IOException
	 * @throws UnsupportedCommOperationException
	 * @throws PortInUseException
	 */
	public HostManager() throws IOException, UnsupportedCommOperationException, PortInUseException{
		super();
		//create in correct sequence
		serialManager_ = new SerialManager(this);
		panel_ = new Panel(serialManager_);
		dataAnalyzer_ = new DataAnalyzer(panel_, serialManager_);
		initComponents();
	}

	/**
	 * Initialize components on frame
	 */
	private void initComponents(){
		setDefaultCloseOperation(javax.swing.WindowConstants.EXIT_ON_CLOSE);
		setBackground(new java.awt.Color(255, 255, 255));
		setResizable(false);
		setTitle(HostManager.PROJECT_NAME);
		getContentPane().add(panel_, java.awt.BorderLayout.CENTER);
		initMenu();
		initListeners();
		pack();
		setLocation(250, 250);
		setVisible(true);
	}

	/**
	 * Initialize menu bar items
	 */
	private void initMenu(){
		menuBar_ = new javax.swing.JMenuBar();
		fileMenu_ = new javax.swing.JMenu();
		fileMenuExit_ = new javax.swing.JMenuItem();
		helpMenu_ = new javax.swing.JMenu();
		helpMenuAbout_ = new javax.swing.JMenuItem();

		fileMenu_.setText("File");
		fileMenuExit_.setText("Exit");
		fileMenu_.add(fileMenuExit_);
		menuBar_.add(fileMenu_);
		helpMenu_.setText("Help");
		helpMenuAbout_.setText("About");
		helpMenu_.add(helpMenuAbout_);
		menuBar_.add(helpMenu_);
		setJMenuBar(menuBar_);
	}
```

```
        /**
     * Initialize all listeners.
     */
    private void initListeners() {
       //add action listener to exit menu item
        fileMenuExit_.addActionListener(new java.awt.event.ActionListener() {
            public void actionPerformed(java.awt.event.ActionEvent evt) {
                fileMenuExitActionPerformed(evt);
            }
        });

      //add action listener to about menu item
        helpMenuAbout_.addActionListener(new java.awt.event.ActionListener() {
            public void actionPerformed(java.awt.event.ActionEvent evt) {
                helpMenuAboutActionPerformed(evt);
            }
        });
    }

    /**
     * Handle action event concerning "exit" menu item.
     * @param evt The ActionEvent
     */
    private void fileMenuExitActionPerformed(ActionEvent evt) {
        System.exit(0);
    }

    /**
     * Handle action event concerning "about" menu item.
     * @param evt The ActionEvent
     */
    private void helpMenuAboutActionPerformed(ActionEvent evt) {
        String[] msg = {HostManager.PROJECT_NAME + " Ver 1.0"};
        JOptionPane.showMessageDialog(this, msg, "About",
                                      JOptionPane.INFORMATION_MESSAGE);
    }

       /**
        * To get DataAnalyzer instance
        * @return DataAnalyzer instance
        */
       public DataAnalyzer getDataAnalyzer() {
               return dataAnalyzer_;
       }

     /**
      * Main method called at start of program.
      * @param argv Command line argument
      * @throws IOException
      * @throws PortInUseException
      * @throws UnsupportedCommOperationException
      */
       public static void main(String [] argv) throws IOException, UnsupportedCommOperationException,
PortInUseException {
               new HostManager();
       }
}
```

3.3.2.2 SerialManager.java

```
package host;
import java.io.IOException;
import java.util.TooManyListenersException;
import java.io.InputStream;
import java.io.OutputStream;
import java.util.Enumeration;
import java.util.Vector;
import gnu.io.CommPortIdentifier;
import gnu.io.CommPort;
import gnu.io.PortInUseException;
import gnu.io.SerialPort;
import gnu.io.SerialPortEvent;
import gnu.io.SerialPortEventListener;
import gnu.io.UnsupportedCommOperationException;

import javax.swing.JOptionPane;


/**
 * SerialManager class, handles all serial communication
 * @author bentzx
 *
 */
public class SerialManager implements SerialPortEventListener {

	private HostManager hostManager_;
	private SerialPort serialPort_ = null;
	private String comPort_ = null;
	private InputStream inputStream_ = null;
	private OutputStream outputStream_ = null;

	//Serial port settings:
	private static final int PARITY = SerialPort.PARITY_NONE;
	private static final int STOPBITS = SerialPort.STOPBITS_2;
	private static final int BAUD = 38400; //38400, 57600, 115200
	private static final int DATABITS = SerialPort.DATABITS_8;

	/**
	 * Constructor
	 * @param hM HostManager
	 */
	public SerialManager(HostManager hM) {
		hostManager_ = hM;
	}

	/**
	 * To select a port
	 * @param msg The message to display in pop-up window
	 * @return The selected port
	 */
	private String selectPort(String msg) {
		Object[] list = listPorts(true);
		String port = null;
		if (list.length > 0) {
			port = (String) JOptionPane.showInputDialog(null, msg, "Input",
				JOptionPane.INFORMATION_MESSAGE, null, list, list[0]);
		}
		else {
			System.out.println("Must connect a serial port");
		}
		if (port == null) {
			System.out.println("Exiting");
		} else {
			port = port.substring(0, port.indexOf(" - "));
			System.out.println(port);
		}
		return port;
	}

	/**
	 * Searches for serial ports
	 * @param available
	 * @return The list of ports
	 */
	private Object[] listPorts(boolean available) {
		Vector <String> result = new Vector <String>();
```

```
        Enumeration portEnum = CommPortIdentifier.getPortIdentifiers();
        while (portEnum.hasMoreElements()) {
                CommPortIdentifier com = (CommPortIdentifier) portEnum
                                .nextElement();
                if (available) {
                        switch (com.getPortType()) {
                        case CommPortIdentifier.PORT_SERIAL:
                                try {
                                        // Test open port to see if it's available
                                        CommPort thePort = com.open("commtest", 50);
                                        thePort.close();
                                        result.add(new String(com.getName()+" - "
                                         + getPortTypeName(com.getPortType())));
                                }
                                catch (PortInUseException e) {
                                        System.err.println(e);
                                }
                                catch (Exception e) {
                                        System.err.println(e);
                                }
                        }
                } else {
                        result.add(new String(com.getName() + " - "
                                        + getPortTypeName(com.getPortType())));
                }
        }
        return result.toArray();
}

/**
 * Determines what type of port
 * @param portType
 * @return The type of port in String format
 */
private String getPortTypeName(int portType) {
        switch (portType) {
        case CommPortIdentifier.PORT_I2C:
                return "I2C";
        case CommPortIdentifier.PORT_PARALLEL:
                return "Parallel";
        case CommPortIdentifier.PORT_RAW:
                return "Raw";
        case CommPortIdentifier.PORT_RS485:
                return "RS485";
        case CommPortIdentifier.PORT_SERIAL:
                return "Serial";
        default:
                return "unknown type";
        }
}

/**
 * Enables serial connection, user chooses COM port
 * @return Boolean whether connection is successful
 */
protected boolean enableSerial(){
        System.out.println("Initializing serial... ");
        comPort_ = selectPort("Select Serial Port");
        if (comPort_==null){
                return false;
        } else {
                return converse();
        }
}

/**
 * Sets up communication channel
 * @return boolean whether connection is successful
 */
```

```
        protected boolean converse() {
                CommPortIdentifier portId = null;
                Enumeration portList = null;
                boolean portFound = false;

                if (serialPort_ != null) {
                        serialPort_.close();
                }
                // Get a list of available ports
                portList = CommPortIdentifier.getPortIdentifiers();
                while (portList.hasMoreElements() && !portFound) {
                        portId = (CommPortIdentifier) portList.nextElement();

                        if (portId.getPortType() == CommPortIdentifier.PORT_SERIAL) {
                                // Tests whether this is the com port we want
                                if (portId.getName().equals(comPort_)) {
                                        portFound = true;

                                        /* listen to serial port's events */
                                        try {
                                                if (serialPort_ != null) {
                                                        serialPort_.close();
                                                }
                                                serialPort_ = (SerialPort) portId.open("videoCam
port",10000); // wait up to 10 seconds for the port to open

                                                // set the Serial Port parameters
                                                serialPort_.setSerialPortParams(BAUD, DATABITS,
STOPBITS, PARITY);

                                                // set flow control hardware to none
                                serialPort_.setFlowControlMode(SerialPort.FLOWCONTROL_NONE);

                                                // get the streams associated with serial port
                                                inputStream_ = serialPort_.getInputStream();
                                                outputStream_ = serialPort_.getOutputStream();

                                                // start listening for events
                                                serialPort_.addEventListener(this);
                                                serialPort_.notifyOnDataAvailable(true);

                                        } catch (PortInUseException e) {
                                                System.out.println("Serial Port already in use.");
                                                System.err.println(e);
                                        } catch (IOException e) {
                                                System.out.println("An IO Exception occurred.");
                                                System.err.println(e);
                                        } catch (TooManyListenersException e) {
                                                System.out.println("too many listeners.");
                                                System.err.println(e);
                                        } catch (UnsupportedCommOperationException e) {
                                                System.out.println("Unknown comm Exception.");
                                                System.err.println(e);
                                        }
                                }
                        }
                }
                if (!portFound) {
                        System.out.println("Port " + comPort_ + " was not found!");
                }
                return portFound;
        }

        /* (non-Javadoc)
         * @see gnu.io.SerialPortEventListener#serialEvent(gnu.io.SerialPortEvent)
         */
        public void serialEvent(SerialPortEvent event) {
                switch (event.getEventType()) {
```

```
                case SerialPortEvent.BI:
                case SerialPortEvent.OE:
                case SerialPortEvent.FE:
                case SerialPortEvent.PE:
                case SerialPortEvent.CD:
                case SerialPortEvent.CTS:
                case SerialPortEvent.DSR:
                case SerialPortEvent.RI:
                        System.out.println("Bad data. Ignore most recent received data packet");
                        break;
                case SerialPortEvent.OUTPUT_BUFFER_EMPTY:
                        break;
                case SerialPortEvent.DATA_AVAILABLE:
                        try {
                                while (inputStream_.available() > 0) {
                                        int i = inputStream_.read();
                                        System.out.println("     " + intToHex(i));
                                        hostManager_.getDataAnalyzer().rxData(i);
                                }
                        }
                        catch (IOException e) {
                                System.err.println("IO Exception occurred reading fr inputStream.");
                                System.err.println(e);
                        }
                        break;
                }
        }

        /**
         * Disconnects serial connection
         * @return Boolean false for disconnected serial
         */
        public boolean disconnect() {
                serialPort_.close();
                return false; // false for disconnection
        }

        /**
         * Automatically disconnects and reconnects serial with previous settings
         */
        public void autoReconnect(){
                AutoReconnectThread aRecon = new AutoReconnectThread(this); //use new thread,
otherwise program freezes
                aRecon.start();
        }

        /**
         * Converts int to hex
         * @param i Int to be converted
         * @return Hex in String format
         */
        private String intToHex(int i) {
                //String hex = Integer.toHexString(i);
                String hex = Integer.toHexString(0x100 | (0x0ff & i)).substring(1);
                if (hex.length() == 1) {
                        hex = "0" + hex;
                }
                return hex;
        }
}

/**
 * Requires this thread for auto reconnect, otherwise, program freezes
 * @author bentzx
 *
 */
class AutoReconnectThread extends Thread {
        private SerialManager serialManager_;
        public AutoReconnectThread(SerialManager sM){
                serialManager_ = sM;
        }

        public void run() {
                System.out.println("Auto-reconnecting");
                serialManager_.converse();
        }
}
```

3.3.2.3 DataAnalyzer.java

```
package host;

import java.io.File;
import java.io.FileNotFoundException;
import java.io.FileOutputStream;
import java.io.IOException;
import java.util.concurrent.ConcurrentLinkedQueue;

/**
 * DataAnalyzer class, handles all data analysis
 * @author bentzx
 *
 */
public class DataAnalyzer {

        private Panel panel_;
        private SerialManager serialManager_;
        private int preambleByteCount_ = 0;
        public static final int BMP_SIZE = 48694;
        private ConcurrentLinkedQueue<Integer> queue_ = null;
        private int trackLatch_ = 0;


        /**
         * Constructor
         * @param p Panel
         * @param sM SerialManager
         */
        public DataAnalyzer(Panel p, SerialManager sM){
                panel_ = p;
                serialManager_ = sM;
                queue_ = new ConcurrentLinkedQueue<Integer>();
        }

        /**
         * Receives serial port data
         * @param i
         */
        public void rxData(int i){
                detectPreamble(i);
                System.out.println(preambleByteCount_);
                if (preambleByteCount_>=4 && preambleByteCount_ <=8){
                        queue_.add(new Integer(i));
                }
                if (preambleByteCount_ == 8){
                        System.out.println("qS: " + queue_.size());
                        if (queue_.size()==BMP_SIZE+5){
                                createPic();
                        }
                        preambleByteCount_ = 0;
                        queue_.clear();
                        System.out.println("qS: " + queue_.size());
                }
        }

        /**
         * Converts int to hex
         * @param i int
         * @return hex
         */
        private String intToHex(int i) {
                //String hex = Integer.toHexString(i);
                String hex = Integer.toHexString(0x100 | (0x0ff & i)).substring(1);
                if (hex.length() == 1) {
                        hex = "0" + hex;
                }
                return hex;
        }

        /**
         * Creates bitmap file from image data
         */
        private void createPic() {
                FileOutputStream fos;
                File tempFile = new File("recordings/temp.bmp");
                try {
                        fos = new FileOutputStream (tempFile);
                        //remove the first element since not needed - the last preamble byte
                        queue_.poll();
                        Integer [] queueArray = queue_.toArray(new Integer[0]);
                        for (int i=0; i<queueArray.length-4; i++){ //ignore subsequent preamble stored
                                fos.write(queueArray[i].intValue());
                        }
                        panel_.initDisplay(tempFile);
                        fos.close();
                        fos = null;
                        System.out.println("initDisplay carried out");

                } catch (FileNotFoundException e) {
                        e.printStackTrace();
                } catch (IOException e) {
                        e.printStackTrace();
                }
                preambleByteCount_ = 0;
                queue_.clear();
        }

        /**
         * Checks for preamble, start increment preambleByteCount when int i matches preamble
         * Keep rxData running as long as preambleByteCount is 4, 5, 6, 7;
         * when reaches 8, know that reached end of second preamble,
         * then createPic and be sure to deduct the subsequent preamble from queue first
         * @param i integer data received
         *
         */
        private void detectPreamble(int i) {
                if (intToHex(i).equals("00") && preambleByteCount_==0){
                        preambleByteCount_++;
                } else if (intToHex(i).equals("00") && preambleByteCount_==1){
                        preambleByteCount_++;
                } else if (intToHex(i).equals("be") && preambleByteCount_==2){
                        preambleByteCount_++;
                } else if (intToHex(i).equals("36") && preambleByteCount_==3){
                        preambleByteCount_++;
                        System.out.println("Found preamble");
                        panel_.getStatusTF().setText("Capturing image...");
                } else if (intToHex(i).equals("aa") && preambleByteCount_==4){
                        preambleByteCount_=5;
                } else if (intToHex(i).equals("aa") && preambleByteCount_==0 &&
(trackLatch_>30000)){  //get system out of latch
                        preambleByteCount_=5;
                        serialManager_.autoReconnect();
                        panel_.getStatusTF().setText("Auto reconnect...");
                } else if (intToHex(i).equals("55") && preambleByteCount_==5){
                        preambleByteCount_=6;
                } else if (intToHex(i).equals("a5") && preambleByteCount_==6){
                        preambleByteCount_=7;
                } else if (intToHex(i).equals("5a") && preambleByteCount_==7){
                        preambleByteCount_=8;
                        trackLatch_ = 0;        //reset trackLatch
                        System.out.println("Found subsequent preamble");
                } else {
                        if (preambleByteCount_<=3 || preambleByteCount_ ==8){
                                preambleByteCount_ = 0;
                                if (preambleByteCount_==0){
                                        trackLatch_++;
                                }
                        } else {
                                preambleByteCount_ = 4;
                        }
                }
        }
}
```

3.3.2.4 Panel.java

```
package host;

import java.awt.image.BufferedImage;
import java.io.File;
import java.io.IOException;

import javax.swing.ImageIcon;
import javax.comm.PortInUseException;
import javax.comm.UnsupportedCommOperationException;
import javax.imageio.*;
import javax.swing.JOptionPane;

/*
 * Panel.java
 *
 * Created on Jul 20, 2008, 1:13:12 PM
 */

/**
 * Panel class, GUI
 * @author bentzx
 */
public class Panel extends javax.swing.JPanel {

        private static final long serialVersionUID = 1L;
        private SerialManager serialManager_;
        private Recorder recorder_;
        private boolean isConnected_ = false;
        private boolean isRecording_ = false;
        private boolean isPlaying_ = false;

    /** Creates new form Panel
     * @throws IOException */
    public Panel(SerialManager sM) throws IOException {
        serialManager_ = sM;
        initComponents();
        addListeners();
        ImageIcon display = new ImageIcon("startupImg.jpg", "Display video");
        picWindowLabel_.setIcon(display);
        recorder_ = new Recorder(this);
    }

    /** This method is called from within the constructor to
     * initialize the form.
     * WARNING: Do NOT modify this code. The content of this method is
     * always regenerated by the Form Editor.
     */
    @SuppressWarnings("unchecked")
    // <editor-fold defaultstate="collapsed" desc="Generated Code">
    private void initComponents() {

        topPanel_ = new javax.swing.JPanel();
        picWindowLabel_ = new javax.swing.JLabel();
        statusPanel_ = new javax.swing.JPanel();
        statusTF_ = new javax.swing.JTextField();
        controlsPanel_ = new javax.swing.JPanel();
        connectionLabel_ = new javax.swing.JLabel();
        recButton_ = new javax.swing.JButton();
        playButton_ = new javax.swing.JButton();
        playlistComboBox_ = new javax.swing.JComboBox();
        connectButton_ = new javax.swing.JButton();
        deleteButton_ = new javax.swing.JButton();

        topPanel_.setBorder(javax.swing.BorderFactory.createTitledBorder(null, "Display",
javax.swing.border.TitledBorder.DEFAULT_JUSTIFICATION,
javax.swing.border.TitledBorder.DEFAULT_POSITION, new java.awt.Font("Tahoma", 0, 11), new
java.awt.Color(0, 153, 255))); // NOI18N

        javax.swing.GroupLayout topPanel_Layout = new javax.swing.GroupLayout(topPanel_);
        topPanel_.setLayout(topPanel_Layout);
        topPanel_Layout.setHorizontalGroup(
            topPanel_Layout.createParallelGroup(javax.swing.GroupLayout.Alignment.LEADING)
            .addGroup(topPanel_Layout.createSequentialGroup()
                .addContainerGap()
                .addComponent(picWindowLabel_, javax.swing.GroupLayout.PREFERRED_SIZE, 248,
javax.swing.GroupLayout.PREFERRED_SIZE)
                .addContainerGap(javax.swing.GroupLayout.DEFAULT_SIZE, Short.MAX_VALUE))
        );
        topPanel_Layout.setVerticalGroup(
            topPanel_Layout.createParallelGroup(javax.swing.GroupLayout.Alignment.LEADING)
            .addGroup(topPanel_Layout.createSequentialGroup()
                .addContainerGap()
                .addComponent(picWindowLabel_, javax.swing.GroupLayout.PREFERRED_SIZE, 192,
javax.swing.GroupLayout.PREFERRED_SIZE)
                .addContainerGap(javax.swing.GroupLayout.DEFAULT_SIZE, Short.MAX_VALUE))
        );

        statusPanel_.setBorder(javax.swing.BorderFactory.createTitledBorder(null, "Status",
javax.swing.border.TitledBorder.DEFAULT_JUSTIFICATION,
javax.swing.border.TitledBorder.DEFAULT_POSITION, new java.awt.Font("Tahoma", 0, 11), new
java.awt.Color(0, 153, 255))); // NOI18N

        statusTF_.addActionListener(new java.awt.event.ActionListener() {
            public void actionPerformed(java.awt.event.ActionEvent evt) {
                statusTF_ActionPerformed(evt);
            }
        });

        javax.swing.GroupLayout statusPanel_Layout = new javax.swing.GroupLayout(statusPanel_);
        statusPanel_.setLayout(statusPanel_Layout);
        statusPanel_Layout.setHorizontalGroup(
            statusPanel_Layout.createParallelGroup(javax.swing.GroupLayout.Alignment.LEADING)
            .addGroup(statusPanel_Layout.createSequentialGroup()
                .addContainerGap()
                .addComponent(statusTF_, javax.swing.GroupLayout.PREFERRED_SIZE, 251,
javax.swing.GroupLayout.PREFERRED_SIZE)
                .addContainerGap(7, Short.MAX_VALUE))
        );
        statusPanel_Layout.setVerticalGroup(
            statusPanel_Layout.createParallelGroup(javax.swing.GroupLayout.Alignment.LEADING)
            .addGroup(javax.swing.GroupLayout.Alignment.TRAILING,
statusPanel_Layout.createSequentialGroup()
                .addContainerGap(javax.swing.GroupLayout.DEFAULT_SIZE, Short.MAX_VALUE)
                .addComponent(statusTF_, javax.swing.GroupLayout.PREFERRED_SIZE,
javax.swing.GroupLayout.DEFAULT_SIZE, javax.swing.GroupLayout.PREFERRED_SIZE)
                .addContainerGap())
        );
        controlsPanel_.setBorder(javax.swing.BorderFactory.createTitledBorder(null, "Controls",
javax.swing.border.TitledBorder.DEFAULT_JUSTIFICATION,
javax.swing.border.TitledBorder.DEFAULT_POSITION, new java.awt.Font("Tahoma", 0, 11), new
java.awt.Color(0, 153, 255))); // NOI18N

        connectionLabel_.setBackground(java.awt.Color.red);
        connectionLabel_.setForeground(java.awt.Color.red);
        connectionLabel_.setOpaque(true);

        recButton_.setText("Rec");
        recButton_.setEnabled(false);
        recButton_.setMaximumSize(new java.awt.Dimension(60, 23));
        recButton_.setMinimumSize(new java.awt.Dimension(60, 23));
        recButton_.setPreferredSize(new java.awt.Dimension(60, 23));

        playButton_.setText("Play");
        playButton_.setEnabled(false);
        playButton_.setMaximumSize(new java.awt.Dimension(60, 23));
        playButton_.setMinimumSize(new java.awt.Dimension(60, 23));
        playButton_.setPreferredSize(new java.awt.Dimension(60, 23));

        playlistComboBox_.setModel(new javax.swing.DefaultComboBoxModel(new String[] { "Select and
play", " ", " " }));

        connectButton_.setText("Connect");
        connectButton_.setMaximumSize(new java.awt.Dimension(100, 23));
        connectButton_.setMinimumSize(new java.awt.Dimension(100, 23));
        connectButton_.setPreferredSize(new java.awt.Dimension(100, 23));

        deleteButton_.setText("Delete");
        deleteButton_.setEnabled(false);
        deleteButton_.setMaximumSize(new java.awt.Dimension(60, 23));
        deleteButton_.setMinimumSize(new java.awt.Dimension(60, 23));
        deleteButton_.setPreferredSize(new java.awt.Dimension(60, 23));

        javax.swing.GroupLayout controlsPanel_Layout = new javax.swing.GroupLayout(controlsPanel_);
        controlsPanel_.setLayout(controlsPanel_Layout);
        controlsPanel_Layout.setHorizontalGroup(
            controlsPanel_Layout.createParallelGroup(javax.swing.GroupLayout.Alignment.LEADING)
            .addGroup(controlsPanel_Layout.createSequentialGroup()
                .addContainerGap()

.addGroup(controlsPanel_Layout.createParallelGroup(javax.swing.GroupLayout.Alignment.LEADING)
                    .addGroup(controlsPanel_Layout.createSequentialGroup()
                        .addComponent(recButton_, javax.swing.GroupLayout.PREFERRED_SIZE, 71,
javax.swing.GroupLayout.PREFERRED_SIZE)
                        .addGap(18, 18, 18)
                        .addComponent(playButton_, javax.swing.GroupLayout.DEFAULT_SIZE, 71,
Short.MAX_VALUE)
                        .addGap(18, 18, 18)
                        .addComponent(deleteButton_, javax.swing.GroupLayout.PREFERRED_SIZE, 70,
javax.swing.GroupLayout.PREFERRED_SIZE))
                    .addGroup(controlsPanel_Layout.createSequentialGroup()
                        .addComponent(connectButton_, javax.swing.GroupLayout.PREFERRED_SIZE,
javax.swing.GroupLayout.DEFAULT_SIZE, javax.swing.GroupLayout.PREFERRED_SIZE)
                        .addGap(30, 30, 30)
                        .addComponent(connectionLabel_, javax.swing.GroupLayout.PREFERRED_SIZE,
118, javax.swing.GroupLayout.PREFERRED_SIZE))
                    .addComponent(playlistComboBox_, 0, 248, Short.MAX_VALUE))
                .addContainerGap())
        );
        controlsPanel_Layout.setVerticalGroup(
            controlsPanel_Layout.createParallelGroup(javax.swing.GroupLayout.Alignment.LEADING)
            .addGroup(controlsPanel_Layout.createSequentialGroup()

.addGroup(controlsPanel_Layout.createParallelGroup(javax.swing.GroupLayout.Alignment.LEADING)
                    .addGroup(controlsPanel_Layout.createSequentialGroup()
                        .addContainerGap()
.addGroup(controlsPanel_Layout.createParallelGroup(javax.swing.GroupLayout.Alignment.LEADING,
false)
                            .addComponent(connectionLabel_, javax.swing.GroupLayout.DEFAULT_SIZE,
javax.swing.GroupLayout.DEFAULT_SIZE, Short.MAX_VALUE)
                            .addComponent(connectButton_, javax.swing.GroupLayout.DEFAULT_SIZE,
javax.swing.GroupLayout.DEFAULT_SIZE, Short.MAX_VALUE)))
                    .addGroup(controlsPanel_Layout.createSequentialGroup()
                        .addGap(52, 52, 52)
                        .addComponent(playlistComboBox_, javax.swing.GroupLayout.PREFERRED_SIZE,
javax.swing.GroupLayout.DEFAULT_SIZE, javax.swing.GroupLayout.PREFERRED_SIZE)))
                .addGap(18, 18, 18)

.addGroup(controlsPanel_Layout.createParallelGroup(javax.swing.GroupLayout.Alignment.BASELINE)
                    .addComponent(recButton_, javax.swing.GroupLayout.PREFERRED_SIZE,
javax.swing.GroupLayout.DEFAULT_SIZE, javax.swing.GroupLayout.PREFERRED_SIZE)
                    .addComponent(deleteButton_, javax.swing.GroupLayout.PREFERRED_SIZE,
javax.swing.GroupLayout.DEFAULT_SIZE, javax.swing.GroupLayout.PREFERRED_SIZE)
                    .addComponent(playButton_, javax.swing.GroupLayout.PREFERRED_SIZE,
javax.swing.GroupLayout.DEFAULT_SIZE, javax.swing.GroupLayout.PREFERRED_SIZE))
                .addContainerGap())
        );

        javax.swing.GroupLayout layout = new javax.swing.GroupLayout(this);
        this.setLayout(layout);
        layout.setHorizontalGroup(
            layout.createParallelGroup(javax.swing.GroupLayout.Alignment.LEADING)
            .addGroup(layout.createSequentialGroup()
                .addContainerGap()
                .addGroup(layout.createParallelGroup(javax.swing.GroupLayout.Alignment.LEADING)
                    .addComponent(controlsPanel_, javax.swing.GroupLayout.PREFERRED_SIZE,
javax.swing.GroupLayout.DEFAULT_SIZE, javax.swing.GroupLayout.PREFERRED_SIZE)
                    .addComponent(topPanel_, javax.swing.GroupLayout.DEFAULT_SIZE,
javax.swing.GroupLayout.DEFAULT_SIZE, Short.MAX_VALUE)
                    .addComponent(statusPanel_, 0, 280, Short.MAX_VALUE))
                .addContainerGap())
        );
        layout.setVerticalGroup(
            layout.createParallelGroup(javax.swing.GroupLayout.Alignment.LEADING)
            .addGroup(layout.createSequentialGroup()
                .addContainerGap()
                .addComponent(topPanel_, javax.swing.GroupLayout.PREFERRED_SIZE,
javax.swing.GroupLayout.DEFAULT_SIZE, javax.swing.GroupLayout.PREFERRED_SIZE)
                .addPreferredGap(javax.swing.LayoutStyle.ComponentPlacement.UNRELATED)
                .addComponent(statusPanel_, javax.swing.GroupLayout.PREFERRED_SIZE,
javax.swing.GroupLayout.DEFAULT_SIZE, javax.swing.GroupLayout.PREFERRED_SIZE)
                .addPreferredGap(javax.swing.LayoutStyle.ComponentPlacement.UNRELATED)
                .addComponent(controlsPanel_, javax.swing.GroupLayout.DEFAULT_SIZE,
javax.swing.GroupLayout.DEFAULT_SIZE, Short.MAX_VALUE)
                .addContainerGap())
        );
    }// </editor-fold>

    private void statusTF_ActionPerformed(java.awt.event.ActionEvent evt) {
        // TODO add your handling code here:
}

    /**
     * Connect to serial port
     * When connected: button says Disconnect, recButton_ enabled, statusTF_ and connectionLabel_
display status
     * @throws PortInUseException
     * @throws UnsupportedCommOperationException
     * @throws IOException
     */
    private void connectButton_ActionPerformed(java.awt.event.ActionEvent evt) throws IOException,
UnsupportedCommOperationException, PortInUseException{
        if (connectButton_.getText().equals("Connect")){
               statusTF_.setText("Connecting...");
               connectionLabel_.setBackground(java.awt.Color.yellow);      // change connection
color to yellow
               isConnected_ = serialManager_.enableSerial();
        } else {
               if (isRecording_){
                      isRecording_=false;
                      recorder_.stop();     //stop recording if still recording
               }
               isConnected_ = serialManager_.disconnect();
        }
        recButton_.setEnabled(isConnected_); // enabled only when serial connection is active
        if (isConnected_){
               //isConnected_ = serialManager_.converse();

               connectButton_.setText("Disconnect");
               statusTF_.setText("Connected. Serial connection is active.");
               connectionLabel_.setBackground(java.awt.Color.green);
               recButton_.setText("Rec");

        } else {
               connectButton_.setText("Connect");
               statusTF_.setText("Serial communication is disconnected.");
               connectionLabel_.setBackground(java.awt.Color.red);
               isRecording_ = false;
        }
    }

    /**
     * Handles rec button behavior
     * @param evt Action event
     */
    private void recButton_ActionPerformed(java.awt.event.ActionEvent evt){
        if (isRecording_){
               recButton_.setText("Rec");
               statusTF_.setText("Recording stopped");
               isRecording_ = false;
               recorder_.stop();
        } else {
               recButton_.setText("Stop");
               statusTF_.setText("Recording");
               isRecording_ = true;
               recorder_.start();
        }

    }

    /**
     * Handles play button behavior
     * @param evt Action event
     */
    private void playButton_ActionPerformed(java.awt.event.ActionEvent evt){
        if (isPlaying_){
               playButton_.setText("Play");
               statusTF_.setText("Playback stopped");
               isPlaying_ = false;

        } else {
               playButton_.setText("Stop");
               statusTF_.setText("Playing");
               isPlaying_ = true;
               String playSelected = (String)playlistComboBox_.getSelectedItem();
               PlayThread play = new PlayThread(recorder_, playSelected); //use new thread,
otherwise button and awt hangs until completed initDisplay
               play.start();
        }
    }

    /**
     * Handles playlist comboBox pop up behavior
     * @param evt Action event
     */
    private void playlistComboBox_Popup(javax.swing.event.PopupMenuEvent evt){
        updatePlaylist();
    }

    /**
     * Handles playlist comboBox close behavior
     * @param evt Action event
     */
    private void playlistComboBox_PopupClosed(javax.swing.event.PopupMenuEvent evt){
        if (playlistComboBox_.getSelectedItem().equals("Select and play")){ //disable the play and
delete buttons if no recording selected
                playButton_.setEnabled(false);
                deleteButton_.setEnabled(false);
        } else {
                playButton_.setEnabled(true);
                deleteButton_.setEnabled(true);
        }
    }

    /**
     * Handles delete button event
     * @param evt Action event
     */
    private void deleteButton_ActionPerformed(java.awt.event.ActionEvent evt){
        int proceed;
        proceed = JOptionPane.showConfirmDialog(null, "Do you really want to delete selected
recording?");
        if(proceed==JOptionPane.YES_OPTION){
                recorder_.deleteFolder((String)playlistComboBox_.getSelectedItem());
        }
    }

    /**
     * Add remaining listeners to action-listening-components, note statusTF_ already added
     */
    private void addListeners() {
        connectButton_.addActionListener(new java.awt.event.ActionListener() {
            public void actionPerformed(java.awt.event.ActionEvent evt) {
                try {
                                connectButton_ActionPerformed(evt);
                        } catch (IOException e) {
                                // TODO Auto-generated catch block
                                e.printStackTrace();
                        } catch (UnsupportedCommOperationException e) {
                                // TODO Auto-generated catch block
                                e.printStackTrace();
                        } catch (PortInUseException e) {
                                // TODO Auto-generated catch block
                                e.printStackTrace();
                        }
            }
        });

        recButton_.addActionListener(new java.awt.event.ActionListener() {
            public void actionPerformed(java.awt.event.ActionEvent evt) {
                recButton_ActionPerformed(evt);
            }
        });
        playButton_.addActionListener(new java.awt.event.ActionListener() {
            public void actionPerformed(java.awt.event.ActionEvent evt) {
                playButton_ActionPerformed(evt);
            }
        });
        playlistComboBox_.addPopupMenuListener(new javax.swing.event.PopupMenuListener() {
            public void popupMenuWillBecomeVisible(javax.swing.event.PopupMenuEvent evt) {
                playlistComboBox_Popup(evt);
            }
            public void popupMenuWillBecomeInvisible(javax.swing.event.PopupMenuEvent evt) {
               playlistComboBox_PopupClosed(evt);
            }
            public void popupMenuCanceled(javax.swing.event.PopupMenuEvent evt) {}
        });
        deleteButton_.addActionListener(new java.awt.event.ActionListener() {
            public void actionPerformed(java.awt.event.ActionEvent evt) {
                deleteButton_ActionPerformed(evt);
            }
        });
    }

    /**
     * Refreshes display
     * @param input Bitmap file
     */
    protected void initDisplay(File input){
        BufferedImage image;
                try {
                        //image = flipV(rotate90SX(ImageIO.read(input)));
                        image = flipH(ImageIO.read(input));
                        File output = new File("recordings/image.jpg");      //create a file for the
output
                ImageIO.write(image, "jpg", output);  //write the image to the destination as jpg
                ImageIcon display = new ImageIcon(ImageIO.read(output)); //use ImageIO.read cos no
caching, otherwise JLabel.setIcon won't update
                picWindowLabel_.setIcon(display);
//              output.delete();
                if (isRecording_){
                        recorder_.store(input);
                }
                } catch (IOException e) {
                        // TODO Auto-generated catch block
                        System.out.println("cannot display");
                        e.printStackTrace();
                }

    }

    /**
     * Flip image horizontally
     * @param bi BufferedImage
     * @return The horizontally flipped image
     */
    private BufferedImage flipH(BufferedImage bi) {
        int width = bi.getWidth();
        int height = bi.getHeight();
        BufferedImage biFlip = new BufferedImage(width, height, bi.getType());
        for(int i=0; i<width; i++)
            for(int j=0; j<height; j++)
                biFlip.setRGB((width-1)-i, j, bi.getRGB(i, j));
        return biFlip;
    }

    /**
     * Updates recordings playlist
     */
    protected void updatePlaylist(){
        playlistComboBox_.removeAllItems();
        playlistComboBox_.addItem("Select and play");
        File [] folders = recorder_.getRecFolders();
        for (int i=0; i<folders.length; i++){
                String folderName = folders[i].getName();
                playlistComboBox_.addItem(folderName);
        }
    }

    /**
     * Check if playing
     * @return Boolean if it's playing
     */
    protected boolean getIsPlaying(){
       return isPlaying_;
    }

    /**
     * To get statusTF_
     * @return statusTF_
     */
    protected javax.swing.JTextField getStatusTF(){
       return statusTF_;
    }

    // Variables declaration - do not modify
    private javax.swing.JButton connectButton_;
    private javax.swing.JLabel connectionLabel_;
    private javax.swing.JPanel controlsPanel_;
    private javax.swing.JButton deleteButton_;
    private javax.swing.JLabel picWindowLabel_;
    private javax.swing.JButton playButton_;
    private javax.swing.JComboBox playlistComboBox_;
    private javax.swing.JButton recButton_;
    private javax.swing.JPanel statusPanel_;
    private javax.swing.JTextField statusTF_;
    private javax.swing.JPanel topPanel_;
    // End of variables declaration

}

/**
 * Requires this thread for play, otherwise, GUI freezes
 * @author bentzx
 *
 */
class PlayThread extends Thread {
       private Recorder recorder_;
       private String playlistSelected_;

       public PlayThread(Recorder rec, String s){
              recorder_ = rec;
              playlistSelected_ = s;
       }

       public void run() {
              recorder_.retrieve(playlistSelected_);
       }
}
```

3.3.2.5 Recorder.java

```
package host;
import java.io.File;
import java.io.FileFilter;
import java.io.FileInputStream;
import java.io.FileNotFoundException;
import java.io.FileOutputStream;
import java.io.IOException;
import java.io.InputStream;
import java.io.OutputStream;
import java.text.DateFormat;
import java.text.SimpleDateFormat;
import java.util.Date;

/**
 * Recorder class, handles all recording and retrieving functions
 * @author bentzx
 *
 */
```

```
public class Recorder {

	private Panel panel_;
	private String folderPathName_;
	private boolean isRecording_ = false;

	/**
	 * Constructor
	 * @param p Panel
	 */
	public Recorder(Panel p){
		panel_ = p;
	}

	/**
	 * Start recording, capture the starting time
	 */
	public void start(){
		isRecording_ = true;
		//create folder that has the name of rec start time
		folderPathName_ = "recordings\\" + getUniqueIdentifier();
		File f = new File(folderPathName_);
		f.mkdirs();
	}

	/**
	 * Store file in the record folder in bmp using filename of time in ms
	 * @param input The input file
	 */
	public void store(File input){
		//note takes bmp
		if (isRecording_){
			// create destination file
			File fileSave = new File(folderPathName_ + "\\" + System.currentTimeMillis()
+ ".bmp");
			try {
				boolean success = fileSave.createNewFile();
				if (success){
					copyFile(input, fileSave);
				}
			} catch (IOException e) {
				// TODO Auto-generated catch block
				e.printStackTrace();
			}

		}
	}

	/**
	 * Stop recording and update the playlist
	 */
	public void stop(){
		isRecording_ = false;
		panel_.updatePlaylist();
	}

	/**
	 * Retrieve recording and play
	 */
	public void retrieve(String playFolderName){
		File[] files = getRecFiles(playFolderName);
		if (files.length==0){
			panel_.getStatusTF().setText("Invalid recording");
		} else {
			int pctPlayed;
			for (int i=0; i<files.length; i++){
				if (panel_.getIsPlaying()){
					panel_.initDisplay(files[i]);
					pctPlayed = (int)Math.ceil((i+1)*100/files.length); //round up
```

```
                              panel_.getStatusTF().setText("Played " + pctPlayed + "%");
                              try {
                                     Thread.sleep(3000);
                              } catch (InterruptedException e) {
                                     // TODO Auto-generated catch block
                                     e.printStackTrace();
                              }
                       } else {
                              break; //break out of play mode when stop button pressed
                       }
                }
         }
  }

  /**
   * To get an array of folders/directories (as File) in the recordings directory
   * @return An array containing folders (File)
   */
  protected File[] getRecFolders(){
         File dir = new File("recordings\\");

      // This filter only returns directories
      FileFilter fileFilter = new FileFilter() {
          public boolean accept(File file) {
              return file.isDirectory();
          }
      };
      File [] files = dir.listFiles(fileFilter);

      return files;
  }

  /**
   * To get an array of files (bmp) in the specified folder in the recordings directory
   * @param folderName The name of the folder in which to get files
   * @return An array containing the files (bmp) in the specified folder
   */
  private File[] getRecFiles(String folderName){
         File dir = new File("recordings\\" + folderName);
         File[] files = dir.listFiles();
         return files;
  }

  /**
   * Delete the folder selected
   * @param folderName The name of the folder for deletion
   */
  protected void deleteFolder(String folderName){
         File dir = new File("recordings\\" + folderName);
         boolean delSuccessful = deleteDir(dir);
         if (delSuccessful){
                panel_.getStatusTF().setText("Delete successful");
         } else {
                panel_.getStatusTF().setText("Unable to delete");
         }
  }

  /**
   * Recursively delete folders in the directory given
   * @param dir Folder to be deleted
   * @return A boolean if deletion is successful
   */
  private boolean deleteDir(File dir) {
   if (dir.isDirectory()) {
       String[] children = dir.list();
       for (int i=0; i<children.length; i++) {
           boolean success = deleteDir(new File(dir, children[i]));
           if (!success) {
               return false;
```

```
                }
            }
        }
        // delete empty directory
        return dir.delete();
    }


       /**
        * Generate a time based unique identifier for photo
        * @return A string containing the unique identifier
        */
       private String getUniqueIdentifier() {
        // Create a unique identifier based upon time.
        DateFormat format = new SimpleDateFormat("ddMMMyyyy_hhmmss_SSSa");
        System.out.println("check uniqueIdentifier" + format.format(new Date()));
        return format.format(new Date());
    }

    /**
     * Copy file from source file to destination file
     * @param src source file
     * @param dst destination file
     */
    private void copyFile(File src, File dst){
        try {
                      InputStream in = new FileInputStream(src);
                      OutputStream out = new FileOutputStream(dst);

                      // Transfer bytes from in to out
                      byte[] buf = new byte[1024];
                      int len;
                      while ((len = in.read(buf)) > 0) {
                          out.write(buf, 0, len);
                      }
                      in.close();
                      out.close();
               } catch (FileNotFoundException e) {
                      // TODO Auto-generated catch block
                      e.printStackTrace();
               } catch (IOException e) {
                      // TODO Auto-generated catch block
                      e.printStackTrace();
               }
    }
}
```