PictureBrowser

CSEE 4840 Embedded System Design

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Chapter 1: Overview

The purpose of our project is to design a picture browser using the DE2 Altera Board.

The Altera Board comes equipped with a USB host, VGA output connection and four pushbuttons among other features. The picture browser finds the JPEG files located on a USB mass storage and display them on a VGA monitor attached to the board. The pushbuttons are then used to browse through the pictures. Two of the buttons are used to move forward and backward on the picture, one button is used to stretch the image while the four one ends the picture browser application. Figure 1 illustrates our system architecture:

In order to achieve this, we installed the µClinux operating system on the SDRAM of the DE2 board. This operating system was configured to detect and mount the USB mass storage. We then wrote software to locate the JPEG files on the USB mass storage and call an image viewer program used for display. µClinux comes with a pre-installed JPEG
image viewer called NXView. However, the JPEG decoding used by the NXView is fairly slow. We decided to have a portion of the JPEG decoding performed on the hardware of the DE2 Altera Board in order to speed up the decoding process. The decoded image was then displayed on the monitor through the VGA interface.
Chapter 2: JPEG Decoder

The inverse discrete cosine transform is completed in hardware due to the many arithmetic operators used in its implementation. The JPEG decoder is used by libjpeg, the software library used by nano-X, nxview, and thus the PictureBrowser software. The seminal paper “Practical Fast 1-D DCT Algorithms with 11 Multiplications” by Christoph Loeffler, Adriaan Ligtenberg and George S. Moschytz was consulted for further information about the transform and graphics from the paper have been used here.

The IDCT requires dequantization of the input values, thus 16 values are sent for each use of the hardware JPEG decoder for a total of 8 full multipliers. The rest of the multipliers are reduced since the input values are multiplied by constant “rotators”. The most simple version is shown in the figure below:

![Diagram of JPEG Decoder](image)

The solid circles represent addition if the lines are solid, and subtraction if the lines are dashed. The squares represent multiplication by the rotators and a lined circle is a multiplication by the square root of 2. The most basic algorithm has the fewest multiplications and additions, but there are multiple multiplications per input; an
undesirable feature which adds delay. To correct this issue, 12 parallel multiplications

can be used at the cost of more additions per line. The figure for the reconstructed odd

portion of the algorithm is shown below:

![Diagram of algorithm](image)

Register Transfer Logic Design, although a familiar topic to the team, was

rejected as a design methodology. The limiting factor was the speed of sequentially

reading and writing input and output values; not the number of gates on the FPGA. The
design team did not feel it necessary to reuse the multipliers since the component fit onto
the FPGA without any problem. The highly parallel design is both simple and reusable
in applications such as DSP where multiple values could arrive at the same time. One
would only have to remove the input registers and output multiplexer. The stages are
also set up to be about the same delay, thus pipelining would be simple to implement.

The hardware synthesizer of Quartus was able to reduce the hardware design to a
point where it could be added to the original design and still fit on the available FPGA.
Although it was suggested that multiple JPEG decoders were possible, it was found that
the hardware design was only limited to the speed at which the 16 values could be loaded
into the device and not the combinatorial logic. The waveform showing the speed at
which the output values are asserted follows:

Another design consideration was the writing of input values to registers. In order
to be able to write in a value at each clock cycle, addressing had to be used. First
instincts led to the use of a simple FSM that sequentially enabled each input register,
however the use of a counter proved to be impossible in one clock cycle, especially since
the design tools would not allow the use of both the rising and falling clock edge. The
addressing has the input values inputed in even addresses and the dequantization values
inputed in the odd addresses. The reading is done on the lowest 8 addresses with the
addresses corresponding to the output names.

The JPEG decoder hardware is implemented in the VHSIC Hardware Description
Language. Original plans called for the shifting of the output values before they were read, however this was not possible with the CAD tools used. The operator need for this shifting, sra, was not available in the IEEE libraries. Quartus included the arithmetic libraries that allowed for the sra operator, but ModelSim did not include the arithmetic libraries. The last shifting is completed in software.

The JPEG decoder was written to interface with the Altera Avalon Bus Fabric. An identifier of “s6” was used for the JPEG decoder. The bus readdata and writedata vectors were of the signed integer type, as were most other signals used to carry the input and dequantization values. Readdata and writedata were 32 bits in length with 31 as the sign bit and 0 as the LSB.
Chapter 3: Hardware System

The JPEG decoder is part of a much larger hardware system taken from Altera's software CD. The original purpose of the system was to demonstrate the VGA and PS/2 capabilities of the DE2 board. Our application required the slowing of the clock to 50MHz, but all other hardware remains a part of the system, even if it is not required for the PictureBrowser. Hardware drivers are used to interact with the VGA framebuffer, pushbuttons, and USB host device. The JPEG decoder is addressed directly in memory since it does not have an interrupt request need.

The original hardware is implemented in Verilog. The JPEG decoder was written in VHDL and the test bench was written in Verilog. No problems were encountered mixing the two languages in the SOPC system builder and the ModelSim simulator.
Chapter 4: PictureBrowser Software

4.1 Hardware/Software Interface:

JPEG decoding in the hardware gets sixteen 32 bit signed integers as input from the software and outputs another set of sixteen 32 bit signed integers to the jidcint.c (lib/libjpeg). Our software component accesses the decoder as if it was a 16 word, 32 bit memory device. We read and write to the Avalon bus through IO_RD_32DIRECT and IOWR_32DIRECT. These two functions which are defined in io.h (lib/libjpeg/) are macros defined after native input/output functions specific to the NIOs2 Board.

Functions signatures for these two functions are as follows:

IOWR_32DIRECT(BASE, OFFSET, DATA);

IORD_32DIRECT(BASE, OFFSET);

The base describes the address that SOPC assigned to the JPEG component (decoder) in the hardware. The offset is 4 bytes since we are writing/reading 32 bits signed integers to/from the hardware. Finally, as mentioned above the data is a 32 bit signed integer.

4.2 Software:

We perform the inverse discrete cosine transform along with dequantization of the JPEG decoder in the hardware, in order to accomplish the task we had to disable the existing features in the libjpeg directory.
4.2.1 IDCT and Dequantization:

4.2.1.1 jddctmanager.c:

This file manages which idct is to be used by the jpeg decoder, we modified this file in order to only allow the slow inverse discrete cosine transform (idct_slow). The IDCT_SLOW is defined in jidctint.c (lib/libjpeg), it only deals with 8 x 8 DCTs.

4.2.1.2 jidcint.c:

Each of the row of the matrix are 32 bits signed integers, they are iteratively (8 times) written to the hardware along with their dequantizer counterparts. The result of the decoding from the hardware is in turn descaled and read into the output matrix.

4.2.2 Button Reader and JPEG finder:

We enabled the driver for the Altera DE2 Board buttons by adding a new module via menuconfig of the uClinux OS. We followed the steps described in the nios2 wiki to install the module. Additionally, we wrote a c program (pictureviewer.c) that recursively iterates given a root directory through directories in order to find JPEG path filenames. This program is case insensitive and does not distinguish between jpg and jpeg file extension. The path filenames are stored into an array of strings (global variable); with the four buttons a user can either view the next picture, previous one, stretch the current picture or just exit the program. The executable of pictureviewer.c is copied into the romfs directory in order to execute it on the board before we zip up the zImage. At boot
up, we automatically mount the USB driver through the modified boot up script. At execution our program goes recursively through folders of the mounted USB mass storage and notify the user of the JPEG files found. The user can now navigate through her JPEG pictures and even stretch them for an enjoyable feeling. However, it is also important to note that nano-X (graphical windowing) has to be killed and restarted everytime we run nxview (interface that calls our modified libjpeg library). This causes a delay in the display of pictures but this delay is significantly less than the same process running using the original libjpeg.
Chapter 5: Support Software

Our project heavily relied on uClinux, below are the existing applications that we took advantage of:

- Nano-X: a graphical windowing application
- Nxview: application that allows display of various file formats
- Busybox: customizable system calls

More documentation about these applications can be found at these websites:

http://nioswiki.jot.com/WikiHome/OperatingSystems/UClinuxDist

http://nioswiki.jot.com/WikiHome/OperatingSystems/%C2%B5Clinux/UsbHost

http://nioswiki.jot.com/WikiHome/OperatingSystems/%C2%B5Clinux/FrameBuffer

Here are some useful screen shots for uClinux menu config:
Main Menu

Arrow keys navigate the menu, <Enter> selects submenus --->. Highlighted letters are hotkeys. Pressing <Y> includes, <N> excludes, <M> modularizes features. Press <Esc> <Esc> to exit, <F1> for Help. Legend: [*] built-in [ ]

excluded --->

Loadable module support --->

Modular setup --->

Plug and Play support --->

Lock devices --->

Networking options --->

assembly Support --->

CSI support --->

20 device support --->

IEEE 1394 (Firewire) support --->

N wins network support --->

send Network support --->

DAA (infrared) support --->

SDN subsystem --->

id CD-ROM drivers (not SCSI, not IDE) --->

Character devices --->

USB support --->

Filesystems --->

Console drivers --->
Arrow keys navigate the menu. (Enter) selects submenus -->.
Highlighted letters are hotkeys. Pressing (y) selects a feature,
while (x) will exclude a feature. Press (Esc)(Esc) to exit, (?) for
Help, (>) for search. Legend: (*) feature is selected [ ] feature is

Busybox Settings -->

- Apps
  - cpuinfo Utilities -->
  - awsmtl -->
  - console Utilities -->
  - dm Utilities -->
  - dmesg -->

- Tools
  - ft Utilities -->

- governor/Password Management Utilities -->
  - linux Ext2 FS Progs -->
  - linux Module Utilities -->
  - linux System Utilities -->
  - nstlaneous Utilities -->
  - Networking Utilities -->
  - proc Utilities -->
  - tools -->
  - system Logging Utilities -->

- Add an Alternate Configuration File
- Save Configuration to an Alternate File
Chapter 6: Summary

The system is able to display JPEG pictures as planned. Implementing the Inverse Discrete Cosine Algorithm on the hardware proved to be faster than its software implementation. For that reason, the pictures are displayed faster. As a matter of fact, our program took about 100 microseconds less than before to open a JPEG picture of about 60 kB. This difference becomes very significant as you increase the picture size and the picture resolution. We were able to flip through the pictures using the pushbuttons.

One of the biggest issues we had was dealing the μClinux operating software. In order to debug and test out design, we had to recompile the kernel every time. That recompilation took about an average of 30-40 minutes. It was also difficult to debug problems on the μClinux software itself since it has a fairly large code base. Also, the DE2 development itself has limited resources. It turned out that the 8MB SDRAM available on it is not the ideal size for a μClinux kernel. However, we were able to carefully program it to run both our software and the operating system. On the hardware side of things, we wish we started working on it early enough because it turned out to be quite a challenge. The main problem was interfacing the rest of the software JPEG decoding with the result from the IDCT performed on hardware. ModelSim was very helpful as a simulation program to test the hardware. Using ModelSim, we were able to
check the validity of the hardware IDCT by comparing it wave outputs to the outputs we would expect in a C IDCT. However, Quartus and ModelSim have different VHDL libraries so we had to try to make our VHDL code compatible to both for testing purposes.

The most important lesson we learned how to handle debugging processes. The nice thing about having a project on picture decoding is that from analyzing the resulting pictures, you can make intelligent guesses on which part of the decoding process is faulty. Also, simulation on hardware is very helpful and we hoped we had started using it from the beginning. It saved us a lot of Quartus compilation time. In addition, the interfacing between hardware and software must be done delicately. We should have first tried a small sample code to test the timing and communication between the two. μClinux is a great operation system, but there are still some improvement to be made.
Chapter 7: Work Breakdown

Jean Kongpinda: Hardware simulation, µClinux configuration, nxview modification.

Stephane Nyombayire: libjpeg modification and testing, software/hardware interface, button configuration.

Joseanibal Colon-Ramos: PictureBrowser software, software integration.

Ian Roth: Hardware IDCT, hardware simulation, nxview modification.
Chapter 8: Code

8.1 Hardware

JPEG_decode.vhd

library ieee;
use ieee.std_logic_1164.all;
use IEEE.std_logic_arith.all;

entity JPEG_decode is

    port ( 
        avs_s6_clk, 
        avs_s6_chipselect, 
        avs_s6_reset_n, 
        avs_s6_read, 
        avs_s6_write : in std_logic; 
        avs_s6_address: in std_logic_vector(3 downto 0); 
        avs_s6_writedata : in signed(31 downto 0); 
        avs_s6_readdata : out signed(31 downto 0) 
    );

end JPEG_decode;

architecture rtl of JPEG_decode is
component reggate is

    port (       
        clk, reset_n : in std_logic;      
        input : in signed(31 downto 0);   
        enable : in std_logic;            
        output : out signed(31 downto 0)  
    );    

end component reggate;

component mux is

    port (       
        input0, input1, input2, input3, 
        input4, input5, input6, input7 : in signed(31 downto 0);    
        sel : in std_logic_vector(2 downto 0);    
        output : out signed(31 downto 0)    
    );    

end component mux;

component quantmux is

    port (       
        input : in signed(31 downto 0);       
        dequant : in signed(31 downto 0);     
        output : out signed(31 downto 0)      
    );    

end component quantmux;

    constant cos0 : signed(31 downto 0) :=  
        "00000000000000000000100110001110" ; -- 2446 FIX (0.298631336)    

    constant cos1 : signed(31 downto 0) :=  
        "00000000000000000000110001111100" ; -- 3196 FIX (0.390180644)    

    constant cos2 : signed(31 downto 0) :=  
        "00000000000000000001000101010001" ; -- 4433 FIX (0.597639344)
constant cos3 : signed(31 downto 0) :=
"00000000000000000000110000111110";-- 6270 FIX
(0.765366865)
cos
constant cos4 : signed(31 downto 0) :=
"00000000000000000001100001111110";-- 7373 FIX
(0.899976223)
cos
constant cos5 : signed(31 downto 0) :=
"00000000000000000010010110100001";-- 9633 FIX
(1.175875602)
cos
constant cos6 : signed(31 downto 0) :=
"00000000000000000011000000001011";-- 12299 FIX
(1.501321110)
cos
constant cos7 : signed(31 downto 0) :=
"00000000000000000011101100100001";-- 15137 FIX
(1.847759065)
cos
constant cos8 : signed(31 downto 0) :=
"00000000000000000011111011000101";-- 16069 FIX
(1.961570560)
cos
constant cos9 : signed(31 downto 0) :=
"00000000000000000011000000001011";-- 16819 FIX
(2.053119869)
cos
constant cos10 : signed(31 downto 0) :=
"00000000000000000011000000001011";-- 20995 FIX
(2.562915447)
cos
constant cos11 : signed(31 downto 0) :=
"00000000000000000011000000001011";-- 25172 FIX
(3.072711026)
cos
constant ncos1 : signed(31 downto 0) :=
"111111111111111111001110000100";-- 3196 FIX
(0.390180644)
cos
constant ncos4 : signed(31 downto 0) :=
"111111111111111111001100110011";-- 7373 FIX
(0.899976223)
cos
constant ncos7 : signed(31 downto 0) :=
"111111111111111111001100110011";-- 15137 FIX
(1.847759065)
cos
constant ncos8 : signed(31 downto 0) :=
"111111111111111111000000100110011";-- 16069 FIX
(1.961570560)
constant ncos10 : signed(31 downto 0):= "1111111111111110101101111110"; -- 20995 FIX (2.562915447)

signal enable0, enable1, enable2, enable3, enable4, enable5, enable6, enable7, enable8, enable9, enable10, enable11, enable12, enable13, enable14, enable15 : std_logic;
signal tobus : signed(31 downto 0);
signal enableout : std_logic;
signal enable : std_logic_vector(15 downto 0);
signal dequant0,
    dequant1,
    dequant2,
    dequant3,
    dequant4,
    dequant5,
    dequant6,
    dequant7 : signed(31 downto 0);
signal input0,
    input1,
    input2,
    input3,
    input4,
    input5,
    input6,
    input7 : signed(31 downto 0);
signal stage10,
    stage11,
    stage12,
    stage13,
    stage14,
    stage15,
    stage16,
    stage17 : signed(31 downto 0);
signal stage22, stage23 : signed(63 downto 0);
signal stage20,
    stage21,
stage24,
stage25,
stage26,
stage27,
stage28,
stage29,
stage210,
stage211,
stage212 : signed(31 downto 0);

signal stage30,
  stage31,
  stage32,
  stage33,
  stage34,
  stage35,
  stage36,
  stage37,
  stage38,
  stage39,
  stage310,
  stage311,
  stage312 : signed(63 downto 0);

signal stage40,
  stage41,
  stage42,
  stage43,
  stage44,
  stage45,
  stage46,
  stage47 : signed(63 downto 0);

signal temp0, temp1, temp2, temp3, temp4, temp5, temp8
  : signed(63 downto 0);

signal temp6, temp7 : signed(31 downto 0);

signal output0,
  output1,
  output2,
  output3,
  output4,
  output5,
  output6,
output7 : signed(31 downto 0);

begin

REGMUX : mux port map (  
    input0 => output0,  
    input1 => output1,  
    input2 => output2,  
    input3 => output3,  
    input4 => output4,  
    input5 => output5,  
    input6 => output6,  
    input7 => output7,  
    sel => avs_s6_address(2 downto 0),  
    output => tobus
);

R0 : reggate port map (  
    clk => avs_s6_clk,  
    reset_n => avs_s6_reset_n,  
    input => avs_s6_writedata,  
    enable => enable0,  
    output => input0
);

R1 : reggate port map (  
    clk => avs_s6_clk,  
    reset_n => avs_s6_reset_n,  
    input => avs_s6_writedata,  
    enable => enable2,  
    output => input1
);

R2 : reggate port map (  
    clk => avs_s6_clk,  
    reset_n => avs_s6_reset_n,  
    input => avs_s6_writedata,  
    enable => enable4,  
    output => input2
);
R3 : reggate port map (  
  clk => avs_s6_clk,  
  reset_n => avs_s6_reset_n,  
  input => avs_s6_writedata,  
  enable => enable6,  
  output => input3  
);  
R4 : reggate port map (  
  clk => avs_s6_clk,  
  reset_n => avs_s6_reset_n,  
  input => avs_s6_writedata,  
  enable => enable8,  
  output => input4  
);  
R5 : reggate port map (  
  clk => avs_s6_clk,  
  reset_n => avs_s6_reset_n,  
  input => avs_s6_writedata,  
  enable => enable10,  
  output => input5  
);  
R6 : reggate port map (  
  clk => avs_s6_clk,  
  reset_n => avs_s6_reset_n,  
  input => avs_s6_writedata,  
  enable => enable12,  
  output => input6  
);  
R7 : reggate port map (  
  clk => avs_s6_clk,  
  reset_n => avs_s6_reset_n,  
  input => avs_s6_writedata,  
  enable => enable14,  
  output => input7  
);
Q0 : reggate port map (  
    clk => avs_s6_clk,  
    reset_n => avs_s6_reset_n,  
    input => avs_s6_writedata,  
    enable => enable1,  
    output => dequant0  
);  

Q1 : reggate port map (  
    clk => avs_s6_clk,  
    reset_n => avs_s6_reset_n,  
    input => avs_s6_writedata,  
    enable => enable3,  
    output => dequant1  
);  

Q2 : reggate port map (  
    clk => avs_s6_clk,  
    reset_n => avs_s6_reset_n,  
    input => avs_s6_writedata,  
    enable => enable5,  
    output => dequant2  
);  

Q3 : reggate port map (  
    clk => avs_s6_clk,  
    reset_n => avs_s6_reset_n,  
    input => avs_s6_writedata,  
    enable => enable7,  
    output => dequant3  
);  

Q4 : reggate port map (  
    clk => avs_s6_clk,  
    reset_n => avs_s6_reset_n,  
    input => avs_s6_writedata,  
    enable => enable9,  
    output => dequant4  
);
Q5 : reggate port map (  
  clk => avs_s6_clk,  
  reset_n => avs_s6_reset_n,  
  input => avs_s6_writedata,  
  enable => enable11,  
  output => dequant5  
);  

Q6 : reggate port map (  
  clk => avs_s6_clk,  
  reset_n => avs_s6_reset_n,  
  input => avs_s6_writedata,  
  enable => enable13,  
  output => dequant6  
);  

Q7 : reggate port map (  
  clk => avs_s6_clk,  
  reset_n => avs_s6_reset_n,  
  input => avs_s6_writedata,  
  enable => enable15,  
  output => dequant7  
);  

DE0 : quantmux port map (  
  input => input0,  
  dequant => dequant0,  
  output => stage10  
);  

DE1 : quantmux port map (  
  input => input1,  
  dequant => dequant1,  
  output => stage11  
);  

DE2 : quantmux port map (  
  input => input2,  
  dequant => dequant2,  
  ...)
output => stage12
);

DE3 : quantmux port map (  
  input => input3,  
  dequant => dequant3,  
  output => stage13  
);

DE4 : quantmux port map (  
  input => input4,  
  dequant => dequant4,  
  output => stage14  
);

DE5 : quantmux port map (  
  input => input5,  
  dequant => dequant5,  
  output => stage15  
);

DE6 : quantmux port map (  
  input => input6,  
  dequant => dequant6,  
  output => stage16  
);

DE7 : quantmux port map (  
  input => input7,  
  dequant => dequant7,  
  output => stage17  
);

temp6 <= stage10 + stage14;
temp7 <= stage10 - stage14;
stage20 <= temp6(31) & temp6(17 downto 0) & "00000000000000"; -- shift by CONST_BITS
stage21 <= temp7(31) & temp7(17 downto 0) & "00000000000000"; -- shift by CONST_BITS
temp8 <= (stage12 + stage16) * cos2;
stage22 <= (stage16 * ncos7) + temp8;
stage23 <= (stage12 * cos3) + temp8;
stage24 <= stage17;
stage25 <= stage15;
stage26 <= stage13;
stage27 <= stage11;
stage28 <= stage24 + stage27;
stage29 <= stage25 + stage26;
stage210 <= stage26 + stage24;
stage211 <= stage25 + stage27;
stage212 <= stage210 + stage211;
stage30 <= stage20 + stage23;
stage31 <= stage21 + stage22;
stage32 <= stage21 - stage22;
stage33 <= stage20 - stage23;
stage34 <= stage24 * cos0;
stage35 <= stage25 * cos9;
stage36 <= stage26 * cos11;
stage37 <= stage27 * cos6;
stage38 <= stage28 * ncos4;
stage39 <= stage29 * ncos10;
stage310 <= stage210 * ncos8;
stage311 <= stage211 * ncos1;
stage312 <= stage212 * cos5;
temp0 <= stage310 + stage312;
temp1 <= stage311 + stage312;
temp2 <= stage34 + stage38 + temp0;
temp3 <= stage35 + stage39 + temp1;
temp4 <= stage36 + stage39 + temp0;
temp5 <= stage37 + stage38 + temp1;
stage40 <= stage30 + temp5;
stage41 <= stage31 + temp4;
stage42 <= stage32 + temp3;
stage43 <= stage33 + temp2;
stage44 <= stage33 - temp2;
stage45 <= stage32 - temp3;
stage46 <= stage31 - temp4;
stage47 <= stage30 - temp5;
output0 <= stage40(63) & stage40(30 downto 0); -- Reduce bit count for multiplied lines and keep the sign
bit
  output1 <= stage41(63) & stage41(30 downto 0);
  output2 <= stage42(63) & stage42(30 downto 0);
  output3 <= stage43(63) & stage43(30 downto 0);
  output4 <= stage44(63) & stage44(30 downto 0);
  output5 <= stage45(63) & stage45(30 downto 0);
  output6 <= stage46(63) & stage46(30 downto 0);
  output7 <= stage47(63) & stage47(30 downto 0);

  enable0 <= avs_s6_write and enable(0) and avs_s6_chipselect;
  enable1 <= avs_s6_write and enable(1) and avs_s6_chipselect;
  enable2 <= avs_s6_write and enable(2) and avs_s6_chipselect;
  enable3 <= avs_s6_write and enable(3) and avs_s6_chipselect;
  enable4 <= avs_s6_write and enable(4) and avs_s6_chipselect;
  enable5 <= avs_s6_write and enable(5) and avs_s6_chipselect;
  enable6 <= avs_s6_write and enable(6) and avs_s6_chipselect;
  enable7 <= avs_s6_write and enable(7) and avs_s6_chipselect;
  enable8 <= avs_s6_write and enable(8) and avs_s6_chipselect;
  enable9 <= avs_s6_write and enable(9) and avs_s6_chipselect;
  enable10 <= avs_s6_write and enable(10) and avs_s6_chipselect;
  enable11 <= avs_s6_write and enable(11) and avs_s6_chipselect;
  enable12 <= avs_s6_write and enable(12) and avs_s6_chipselect;
  enable13 <= avs_s6_write and enable(13) and avs_s6_chipselect;
  enable14 <= avs_s6_write and enable(14) and avs_s6_chipselect;
  enable15 <= avs_s6_write and enable(15) and avs_s6_chipselect;
avs_s6_chipselect;

with avs_s6_address select
    enable <= "0000000000000001" when "0000",
               "0000000000000010" when "0001",
               "0000000000000100" when "0010",
               "0000000000010000" when "0011",
               "0000000000010000" when "0100",
               "0000000001000000" when "0101",
               "0000000001000000" when "0110",
               "0000000010000000" when "0111",
               "0000000100000000" when "1000",
               "0000001000000000" when "1001",
               "0000100000000000" when "1010",
               "0010000000000000" when "1011",
               "0100000000000000" when "1100",
               "1000000000000000" when "1101",
               "0000000000000000" when others;

enableout <= avs_s6_read and avs_s6_chipselect;

with enableout select
    avs_s6_readdata <= tobus when '1',
                   "00000000000000000000000000000000" when others;

end architecture rtl;
library ieee;
use ieee.std_logic_1164.all;
use IEEE.std_logic_arith.all;

entity mux is

  port ( 
    input0, input1, input2, input3, 
    input4, input5, input6, input7 : in signed(31
downto 0);
    sel : in std_logic_vector(2 downto 0);
    output : out signed(31 downto 0)
  );
end mux;

architecture behavior of mux is
begin
  with sel select
    output(31 downto 0) <= input0(31 downto 0) when "000",
    input1(31 downto 0) when "001",
    input2(31 downto 0) when "010",
    input3(31 downto 0) when "011",
    input4(31 downto 0) when "100",
    input5(31 downto 0) when "101",
    input6(31 downto 0) when "110",
    input7(31 downto 0) when others;
end behavior;
library ieee;
use ieee.std_logic_1164.all;
use IEEE.std_logic_arith.all;

entity quantmux is

  port (  
    input : in signed(31 downto 0);
    dequant : in signed(31 downto 0);
    output : out signed(31 downto 0)
  );

end quantmux;

architecture behavior of quantmux is

  signal temp : signed(31 downto 0);
  signal multi : signed (63 downto 0);

begin

  multi <= (input * dequant);
  temp <= multi(31 downto 0);

  with dequant select
    output <= input when
    "00000000000000000000000000000001",
    temp when others;

end behavior;
library ieee;
use ieee.std_logic_1164.all;
use ieee.std_logic_arith.all;

entity reggate is
  port(
    clk, reset_n : in std_logic;
    input : in signed(31 downto 0);
    enable : in std_logic;
    output : out signed(31 downto 0)
  );
end reggate;

architecture behavior of reggate is
begin
  process (clk, reset_n, enable)
  begin
    if reset_n = '0' then
      output <= "00000000000000000000000000000000";
    elsif clk'event and clk = '1' then
      if enable = '1' then
        output <= input;
      end if;
    end if;
  end process;
end behavior;
module tb;

reg avs_s6_clk;
reg avs_s6_chipselect;
reg avs_s6_reset_n;
reg avs_s6_read;
reg avs_s6_write;
reg [3:0] avs_s6_address;
reg [31:0] avs_s6_writedata;

wire [31:0] avs_s6_readdata;

JPEG_decode UUT (  
    avs_s6_clk,
    avs_s6_chipselect,
    avs_s6_reset_n,
    avs_s6_read,
    avs_s6_write,
    avs_s6_address,
    avs_s6_writedata,
    avs_s6_readdata  );

initial begin

    avs_s6_clk <= 0;
    avs_s6_chipselect <= 0;
    avs_s6_reset_n <= 0;
    avs_s6_read <= 0;
    avs_s6_write <= 0;
    avs_s6_writedata <= 0;
    avs_s6_address <= 0;

    #200;
    avs_s6_reset_n <= 1'bl1;
    #310;

nios_write(4'd0, 32'd50);
nios_write(4'd1, 32'd1);
nios_write(4'd2, 32'd50);
nios_write(4'd3, 32'd1);
nios_write(4'd4, 32'd50);
nios_write(4'd5, 32'd1);
nios_write(4'd6, 32'd50);
nios_write(4'd7, 32'd1);
nios_write(4'd8, 32'd50);
nios_write(4'd9, 32'd1);
nios_write(4'd10, 32'd50);
nios_write(4'd11, 32'd1);
nios_write(4'd12, 32'd50);
nios_write(4'd13, 32'd1);
nios_write(4'd14, 32'd50);
nios_write(4'd15, 32'd1);

#1000;
nios_read(4'd0);
nios_read(4'd1);
nios_read(4'd2);

// nios_write(32'h80);
#1000;
$finish;

end

always #20 avs_s6_clk <= ~avs_s6_clk;

task nios_read;
input [31:0] addr;
begin

@(posedge avs_s6_clk);
avs_s6_address <= addr;
avs_s6_writedata <= 32'h0;
avs_s6_read <= 1'b1;
avs_s6_write <= 1'b0;
avs_s6_chipselect <= 1'b1;

@(posedge avs_s6_clk )
// address <= 0;
avs_s6_writedata <= 32'h0;
avs_s6_read <= 1'b0;
avs_s6_chipselect <= 1'b0;

@(posedge avs_s6_clk )
end
downtask
task nios_write;
input [3:0] addr;
inout [31:0] data;
begin

@(posedge avs_s6_clk )
avs_s6_address <= addr;
avs_s6_writedata <= data;
avs_s6_read <= 1'b0;
avs_s6_write <= 1'b1;
avs_s6_chipselect <= 1'b1;

@(posedge avs_s6_clk )
avs_s6_address <= 0;
avs_s6_writedata <= data;
avs_s6_read <= 1'b0;
avs_s6_write <= 1'b0;
avs_s6_chipselect <= 1'b0;
 @(posedge avs_s6_clk )

end
downtask
endmodule
8.2 Software

io.h

#ifndef __IO_H__
define __IO_H__

/*****************************/
/*****************************/

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/* IO Header file for Nios II Toolchain */

#include "alt_types.h"
#ifdef __cplusplus
extern "C"
{
#endif /* __cplusplus */

#ifndef SYSTEM_BUS_WIDTH
#error SYSTEM_BUS_WIDTH undefined
#endif
/* Dynamic bus access functions */

#define __IO_CALC_ADDRESS_DYNAMIC(BASE, OFFSET) 
  (((void *)(((alt_u8*)BASE) + (OFFSET))))
#define IORD_32DIRECT(BASE, OFFSET) 
  __builtin_ldwio (__IO_CALC_ADDRESS_DYNAMIC ((BASE),
                      (OFFSET)))
#define IORD_16DIRECT(BASE, OFFSET) 
  __builtin_ldhuio (__IO_CALC_ADDRESS_DYNAMIC ((BASE),
                      (OFFSET)))
#define IORD_8DIRECT(BASE, OFFSET) 
  __builtin_ldbuio (__IO_CALC_ADDRESS_DYNAMIC ((BASE),
                      (OFFSET)))
#define IOWR_32DIRECT(BASE, OFFSET, DATA) 
  __builtin_stwio (__IO_CALC_ADDRESS_DYNAMIC ((BASE),
                      (OFFSET)), (DATA))
#define IOWR_16DIRECT(BASE, OFFSET, DATA) 
  __builtin_sthio (__IO_CALC_ADDRESS_DYNAMIC ((BASE),
                      (OFFSET)), (DATA))
#define IOWR_8DIRECT(BASE, OFFSET, DATA) 
  __builtin_stbio (__IO_CALC_ADDRESS_DYNAMIC ((BASE),
                      (OFFSET)), (DATA))

/* Native bus access functions */

#define __IO_CALC_ADDRESS_NATIVE(BASE, REGNUM) 
  (((void *)(((alt_u8*)BASE) + ((REGNUM) * 
                  (SYSTEM_BUS_WIDTH/8)))))
#define IORD(BASE, REGNUM) 
  __builtin_ldwio (__IO_CALC_ADDRESS_NATIVE ((BASE),
                      (REGNUM)))
#define IOWR(BASE, REGNUM, DATA) 
  __builtin_stwio (__IO_CALC_ADDRESS_NATIVE ((BASE),
                      (REGNUM)), (DATA))

#ifdef __cplusplus
}
/* jddctmgr.c */

/*
 * jddctmgr.c
 *
 * Copyright (C) 1994-1996, Thomas G. Lane.
 * This file is part of the Independent JPEG Group's software.
 * For conditions of distribution and use, see the accompanying
 * README file.
 *
 * This file contains the inverse-DCT management logic. This code selects
 * a particular IDCT implementation to be used, and it performs related
 * housekeeping chores. No code in this file is executed per IDCT step,
 * only during output pass setup.
 *
 * Note that the IDCT routines are responsible for performing
 * coefficient dequantization as well as the IDCT proper. This module sets
 * up the dequantization multiplier table needed by the IDCT routine.
 */

#define JPEG_INTERNALS
#include "jinclude.h"
#include "jpeglib.h"
#include "jdct.h" /* Private declarations for DCT subsystem */
/ * The decompressor input side (jdinput.c) saves away
  * the appropriate
  * quantization table for each component at the start of
  * the first
  * scan
  * involving that component. (This is necessary in
  * order to
  * correctly
  * decode files that reuse Q-table slots.)
  * When we are ready to make an output pass, the saved
Q-table is
  * converted
  * to a multiplier table that will actually be used by
the IDCT
routine.
  * The multiplier table contents are IDCT-method-
dependent. To
support
  * application changes in IDCT method between scans, we
  * can remake
the
  * multiplier tables if necessary.
  * In buffered-image mode, the first output pass may
  * occur before
any data
  * has been seen for some components, and thus before
their Q-tables
  * have
  * been saved away. To handle this case, multiplier
  * tables are
preset
  * to zeroes; the result of the IDCT will be a neutral
  * gray level.
  */

/* Private subobject for this module */
typedef struct {
    struct jpeg_inverse_dct pub; /* public fields */
}

/* This array contains the IDCT method code that each multiplier table
 * is currently set up for, or -1 if it's not yet set up.
 * The actual multiplier tables are pointed to by dct_table in the
 * per-component comp_info structures.
 */
int cur_method[MAX_COMPONENTS];
} my_idct_controller;

typedef my_idct_controller * my_idct_ptr;

/* Allocated multiplier tables: big enough for any supported variant */

typedef union {
    ISLOW_MULT_TYPE islow_array[DCTSIZE2];
#ifdef DCT_IFAST_SUPPORTED
    IFAST_MULT_TYPE ifast_array[DCTSIZE2];
#endif
#ifdef DCT_FLOAT_SUPPORTED
    FLOAT_MULT_TYPE float_array[DCTSIZE2];
#endif
} multiplier_table;

/* The current scaled-IDCT routines require ISLOW-style multiplier tables,
 * so be sure to compile that code if either ISLOW or SCALING is
* Prepare for an output pass.  
* Here we select the proper IDCT routine for each component and build  
* a matching multiplier table.  
*/

METHODDEF(void)

start_pass (j_decompress_ptr cinfo) 
{
  my_idct_ptr idct = (my_idct_ptr) cinfo->idct;
  int ci, i;
  jpeg_component_info *compptr;
  int method = 0;
  inverse_DCT_method_ptr method_ptr = NULL;
  JQUANT_TBL * qtbl;

  for (ci = 0, compptr = cinfo->comp_info; ci <
    cinfo->num_components;
    ci++, compptr++) {
    /* Select the proper IDCT routine for this component's scaling  
    */
    switch (compptr->DCT_scaled_size) {
#ifdef IDCT_SCALING_SUPPORTED
    case 1:
      method_ptr = jpeg_idct_1x1;
      method = JDCT_ISLOW; /* jidctred uses
islow-style table */
break;
case 2:
    method_ptr = jpeg_idct_2x2;
    method = JDCT_ISLOW; /* jidctred uses
islow-style table */
break;
case 4:
    method_ptr = jpeg_idct_4x4;
    method = JDCT_ISLOW; /* jidctred uses
islow-style table */
break;
#endif
case DCTSIZE:
    method_ptr = jpeg_idct_islow;
    method = JDCT_ISLOW;
break;

switch (cinfo->dct_method) {
#ifdef DCT_ISLOW_SUPPORTED
    case JDCT_ISLOW:
        method_ptr = jpeg_idct_islow;
        method = JDCT_ISLOW;
        break;
#endif
#ifdef DCT_IFAST_SUPPORTED
    case JDCT_IFAST:
        method_ptr = jpeg_idct_islow;
        method = JDCT_ISLOW;
        break;
#endif
#ifdef DCT_FLOAT_SUPPORTED
    case JDCT_FLOAT:
        method_ptr = jpeg_idct_islow;
        method = JDCT_ISLOW;
        break;
#endif
    default:
        ERREXIT(cinfo, JERR_NOT_COMPILED);
        break;
{ 
    break;
    default:
        ERREXIT1(cinfo, JERR_BAD_DCTSIZE, compptr->DCT_scaled_size);
        break;
    }
}

idct->pub.inverse_DCT[ci] = method_ptr;
/* Create multiplier table from quant table.
 * However, we can skip this if the component is uninteresting
 * or if we already built the table. Also, if no quant table
 * has yet been saved for the component, we leave the
 * multiplier table all-zero; we'll be reading zeroes from the
 * coefficient controller's buffer anyway.
 */
if (! compptr->component_needed || idct->cur_method[ci] == method)
    continue;
qtbl = compptr->quant_table;
    if (qtbl == NULL) /* happens if no
data yet for component */
    continue;
idct->cur_method[ci] = method;
switch (method) {
    #ifdef PROVIDE_ISLOW_TABLES
        case JDCT_ISLOW:
            { /* For LL&M IDCT method, multipliers are equal
to raw quantization
            * coefficients, but are stored as ints to
ensure access
efficiency.
            */
            ISLOW_MULT_TYPE * ismtbl = (ISLOW_MULT_TYPE *)
                compptr->dct_table;
            break;
        }
for (i = 0; i < DCTSIZE2; i++) {
    ismtbl[i] = (ISLOW_MULT_TYPE) qtbl->quantval[i];
}
}
break;
#endif
#endif DCT_IFAST_SUPPORTED
case JDCT_IFAST:
{
    /* For LL&M IDCT method, multipliers are equal to raw quantization coefficients, but are stored as ints to ensure access efficiency.
     */
    ISLOW_MULT_TYPE * ismtbl = (ISLOW_MULT_TYPE *) compptr->dct_table;
    for (i = 0; i < DCTSIZE2; i++) {
        ismtbl[i] = (ISLOW_MULT_TYPE) qtbl->quantval[i];
    }
}
break;
#endif
#endif DCT_FLOAT_SUPPORTED
case JDCT_FLOAT:
{
    /* For LL&M IDCT method, multipliers are equal to raw quantization coefficients, but are stored as ints to ensure access efficiency.
     */
    ISLOW_MULT_TYPE * ismtbl = (ISLOW_MULT_TYPE *) compptr->dct_table;
    for (i = 0; i < DCTSIZE2; i++) {
        ismtbl[i] = (ISLOW_MULT_TYPE) qtbl->quantval[i];
    }
    break;
#endif
default:
    ERREXIT(cinfo, JERR_NOT_COMPILED);
    break;
}
}


/

* Initialize IDCT manager.
*/

GLOBAL(void)
jinit_inverse_dct (j_decompress_ptr cinfo)
{
    my_idct_ptr idct;
    int ci;
    jpeg_component_info *compptr;

    idct = (my_idct_ptr)
        (*cinfo->mem->alloc_small) ((j_common_ptr) cinfo,
                                 JPOOL_IMAGE,
                                 SIZEOF
                                 (my_idct_controller));
    cinfo->idct = (struct jpeg_inverse_dct *) idct;
    idct->pub.start_pass = start_pass;

    for (ci = 0, compptr = cinfo->comp_info; ci <
         cinfo->num_components;
         ci++, compptr++) {
        /* Allocate and pre-zero a multiplier table for each
           component */
        compptr->dct_table =
            (*cinfo->mem->alloc_small) ((j_common_ptr) cinfo,
                                        JPOOL_IMAGE,
                                        SIZEOF
                                        (multiplier_table));
        MEMZERO(compptr->dct_table, SIZEOF
(multiplier_table));
/* Mark multiplier table not yet set up for any
method */
    idct->cur_method[ci] = -1;
}
}

jidctint.c
/*
 * jidctint.c
 *
 * Copyright (C) 1991-1998, Thomas G. Lane.
 * This file is part of the Independent JPEG Group's software.
 * For conditions of distribution and use, see the accompanying README file.
 *
 * This file contains a slow-but-accurate integer implementation of the
 * inverse DCT (Discrete Cosine Transform). In the IJG code, this routine
 * must also perform dequantization of the input coefficients.
 *
 * A 2-D IDCT can be done by 1-D IDCT on each column
 * followed by 1-D IDCT
 * on each row (or vice versa, but it's more convenient to emit a row at
 * a time). Direct algorithms are also available, but they are much more
 * complex and seem not to be any faster when reduced to code.
 *
 * This implementation is based on an algorithm described in
 * C. Loeffler, A. Ligtenberg and G. Moschytz,
 "Practical Fast 1-D DCT
 * Algorithms with 11 Multiplications", Proc. Int'l. Conf. on Acoustics,
 * Speech, and Signal Processing 1989 (ICASSP '89),

*/

/* Mark multiplier table not yet set up for any
method */
    idct->cur_method[ci] = -1;
}
* The primary algorithm described there uses 11 multiplies and 29 adds.
* We use their alternate method with 12 multiplies and 32 adds.
* The advantage of this method is that no data path contains more than one
  multiplication; this allows a very simple and accurate implementation in
  scaled fixed-point arithmetic, with a minimal number of shifts.
*/

#define JPEG_INTERNALS
#include "jinclude.h"
#include "jpeglib.h"
#include "jdct.h" /* Private declarations for DCT subsystem */

#include <io.h>
#include <stdio.h>

#if !defined DCT_ISLOW_SUPPORTED

/*
 * This module is specialized to the case DCTSIZE = 8.
 */

#if DCTSIZE != 8
  Sorry, this code only copes with 8x8 DCTs. /* deliberate syntax err */
#endif

#define IOWR_JPEG_DATA(base, offset, data) \
  IOWR_32DIRECT(base, (offset) * 4, data)
#define JPEG_BASE 0x00400000
#define IORD_JPEG_DATA(base, offset) \
  IORD_32DIRECT(base, (offset) * 4, data)
IORD_32DIRECT(base, (offset) * 4)

/*
 * The poop on this scaling stuff is as follows:
 * Each 1-D IDCT step produces outputs which are a
 * factor of $\sqrt{N}$
 * larger than the true IDCT outputs. The final outputs
 * are therefore
 * a factor of $N$ larger than desired; since $N=8$ this can
 * be cured by
 * a simple right shift at the end of the algorithm.
 * The advantage of
 * this arrangement is that we save two multiplications
 * per 1-D IDCT,
 * because the $y_0$ and $y_4$ inputs need not be divided by
 * $\sqrt{N}$.
 *
 * We have to do addition and subtraction of the integer
 * inputs, which
 * is no problem, and multiplication by fractional
 * constants, which is
 * a problem to do in integer arithmetic. We multiply
 * all the constants
 * by CONST_SCALE and convert them to integer constants
 * (thus retaining
 * CONST_BITS bits of precision in the constants).
 * After doing a
 * multiplication we have to divide the product by
 * CONST_SCALE, with proper
 * rounding, to produce the correct output. This
 * division can be done
 * cheaply as a right shift of CONST_BITS bits. We
 * postpone shifting
 * as long as possible so that partial sums can be added
 * together with
 * full fractional precision.
 *
 * The outputs of the first pass are scaled up by
 * PASS1_BITS bits so that
they are represented to better-than-integral precision. These outputs require $\text{BITS\_IN\_JSAMPLE} + \text{PASS1\_BITS} + 3$ bits; this fits in a 16-bit word with the recommended scaling. (To scale up 12-bit sample data further, an intermediate INT32 array would be needed.)

To avoid overflow of the 32-bit intermediate results in pass 2, we must have $\text{BITS\_IN\_JSAMPLE} + \text{CONST\_BITS} + \text{PASS1\_BITS} \leq 26$. Error analysis shows that the values given below are the most effective.

```c
#if \text{BITS\_IN\_JSAMPLE} == 8
#define \text{CONST\_BITS} 13
#define \text{PASS1\_BITS} 2
#else
#define \text{CONST\_BITS} 13
#define \text{PASS1\_BITS} 1 /* lose a little precision to avoid overflow */
#endif
```

/* Multiply an INT32 variable by an INT32 constant to yield an INT32 result. For 8-bit samples with the recommended scaling, all the variable and constant values involved are no more than 16 bits wide, so a 16x16->32 bit multiply can be used instead of a full 32x32 multiply. For 12-bit samples, a full 32-bit multiplication will be needed. */

```c
#if \text{BITS\_IN\_JSAMPLE} == 8
#define \text{MULTIPLY}(\text{var,}\text{const}) \text{MULTIPLY16C16(\text{var,}\text{const})}
#else
```
#define MULTIPLY(var,const) ((var) * (const))
#endif

/* Dequantize a coefficient by multiplying it by the multiplier-table entry; produce an int result. In this module, both inputs and result are 16 bits or less, so either int or short multiply will work. */
#define DEQUANTIZE(coef,quantval) (((ISLOW_MULT_TYPE)(coef)) * (quantval))

/*
 * Perform dequantization and inverse DCT on one block of coefficients.
 */
GLOBAL(void)
jpeg_idct_islow (j_decompress_ptr cinfo, jpeg_component_info * compptr,
                JCOEFPTR coef_block,
                JSAMPARRAY output_buf, JDIMENSION output_col)
{
    int counterint;
    int cycleint;
    JCOEFPTR inptr;
    JCOEFPTR quantptr;
    ISLOW_MULT_TYPE * wsptr;
    JSAMPROW outptr;
    JSAMPLE *range_limit = IDCT_range_limit(cinfo);
    int ctr;
    int workspace[DCTSIZE2]; /* buffers data between passes */
    SHIFT_TEMPS

    /* Pass 1: process columns from input, store into work...*/
}
array. */
/* Note results are scaled up by sqrt(8) compared to a true IDCT; */
/* furthermore, we scale the results by 2**PASS1_BITS. */

inptr = coef_block;
quantptr = (ISLOW_MULT_TYPE *) compptr->dct_table;
wspt = workspace;
for (ctr = DCTSIZE; ctr > 0; ctr--) {
    /* Due to quantization, we will usually find that many of the input
     * coefficients are zero, especially the AC terms. We can exploit this
     * by short-circuiting the IDCT calculation for any column in which all
     * the AC terms are zero. In that case each output is equal to the
     * DC coefficient (with scale factor as needed).
     * With typical images and quantization tables, half or more of the
     * column DCT calculations can be simplified this way.
     */

    if (inptr[DCTSIZE*1] == 0 && inptr[DCTSIZE*2] == 0 &&
        inptr[DCTSIZE*3] == 0 && inptr[DCTSIZE*4] == 0 &&
        inptr[DCTSIZE*5] == 0 && inptr[DCTSIZE*6] == 0 &&
        inptr[DCTSIZE*7] == 0) {
        /* AC terms all zero */
        int dcval = DEQUANTIZE(inptr[DCTSIZE*0], quantptr[DCTSIZE*0]) << PASS1_BITS;

        wsptr[DCTSIZE*0] = dcval;
        wsptr[DCTSIZE*1] = dcval;
        wsptr[DCTSIZE*2] = dcval;
        wsptr[DCTSIZE*3] = dcval;
        wsptr[DCTSIZE*4] = dcval;
        wsptr[DCTSIZE*5] = dcval;
wsptr[DCTSIZE*6] = dcval;
wsptr[DCTSIZE*7] = dcval;

inptr++; /* advance pointers to next column */
quantptr++;
wsptr++;
continue;
}

IOWR_JPEG_DATA(JPEG_BASE,0,inptr[DCTSIZE*0]);
IOWR_JPEG_DATA(JPEG_BASE,1,quantptr[DCTSIZE*0]);
IOWR_JPEG_DATA(JPEG_BASE,2,inptr[DCTSIZE*1]);
IOWR_JPEG_DATA(JPEG_BASE,3,quantptr[DCTSIZE*1]);
IOWR_JPEG_DATA(JPEG_BASE,4,inptr[DCTSIZE*2]);
IOWR_JPEG_DATA(JPEG_BASE,5,quantptr[DCTSIZE*2]);
IOWR_JPEG_DATA(JPEG_BASE,6,inptr[DCTSIZE*3]);
IOWR_JPEG_DATA(JPEG_BASE,7,quantptr[DCTSIZE*3]);
IOWR_JPEG_DATA(JPEG_BASE,8,inptr[DCTSIZE*4]);
IOWR_JPEG_DATA(JPEG_BASE,9,quantptr[DCTSIZE*4]);
IOWR_JPEG_DATA(JPEG_BASE,10,inptr[DCTSIZE*5]);
IOWR_JPEG_DATA(JPEG_BASE,11,quantptr[DCTSIZE*5]);
IOWR_JPEG_DATA(JPEG_BASE,12,inptr[DCTSIZE*6]);
IOWR_JPEG_DATA(JPEG_BASE,13,quantptr[DCTSIZE*6]);
IOWR_JPEG_DATA(JPEG_BASE,14,inptr[DCTSIZE*7]);
IOWR_JPEG_DATA(JPEG_BASE,15,quantptr[DCTSIZE*7]);

/*
for(counterint = 0; counterint < 10; counterint++) {
    cycleint = cycleint++;
}
*/

wsptr[DCTSIZE*0]=(int) DESCALE(IORD_JPEG_DATA(JPEG_BASE,0), CONST_BITS-PASS1_BITS);
wsptr[DCTSIZE*1]=(int) DESCALE(IORD_JPEG_DATA(JPEG_BASE,1), CONST_BITS-PASS1_BITS);
wsptr[DCTSIZE*2]=(int) DESCALE(IORD_JPEG_DATA(JPEG_BASE,2), CONST_BITS-PASS1_BITS);
wsptr[DCTSIZE*3]=(int) DESCALE(IORD_JPEG_DATA
(JPEG_BASE,3), CONST_BITS-PASS1_BITS);
    wsptr[DCTSIZE*4]=(int) DESCALE(IORD_JPEG_DATA
(JPEG_BASE,4), CONST_BITS-PASS1_BITS);
    wsptr[DCTSIZE*5]=(int) DESCALE(IORD_JPEG_DATA
(JPEG_BASE,5), CONST_BITS-PASS1_BITS);
    wsptr[DCTSIZE*6]=(int) DESCALE(IORD_JPEG_DATA
(JPEG_BASE,6), CONST_BITS-PASS1_BITS);
    wsptr[DCTSIZE*7]=(int) DESCALE(IORD_JPEG_DATA
(JPEG_BASE,7), CONST_BITS-PASS1_BITS);

    inprr++;               /* advance pointers to next
    column */
    quantptr++;
    wsptr++;
}

/* Pass 2: process rows from work array, store into
output array. */
/* Note that we must descale the results by a factor
of 8 == 2**3, */
/* and also undo the PASS1_BITS scaling. */
IOWR_JPEG_DATA(JPEG_BASE,1,1);
IOWR_JPEG_DATA(JPEG_BASE,3,1);
IOWR_JPEG_DATA(JPEG_BASE,5,1);
IOWR_JPEG_DATA(JPEG_BASE,7,1);
IOWR_JPEG_DATA(JPEG_BASE,9,1);
IOWR_JPEG_DATA(JPEG_BASE,11,1);
IOWR_JPEG_DATA(JPEG_BASE,13,1);
IOWR_JPEG_DATA(JPEG_BASE,15,1);

wsptr = workspace;
for (ctr = 0; ctr < DCTSIZE; ctr++) {
    outptr = output_buf[ctr] + output_col;
    /* Rows of zeroes can be exploited in the same way
    as we did with columns.
    * However, the column calculation has created many
    nonzero AC terms, so
    * the simplification applies less often (typically
    5% to 10% of the time).
* On machines with very fast multiplication, it's possible that the
  * test takes more time than it's worth. In that case this section
  * may be commented out.

*/

#ifndef NO_ZERO_ROW_TEST  
  && wsptr[4] == 0 &&  
    /* AC terms all zero */  
    JSAMPLE dcval = range_limit[(int) DESCALE((INT32)  
      wsptr[0], PASS1_BITS+3)  
      & RANGE_MASK];

    outptr[0] = dcval;  
    outptr[1] = dcval;  
    outptr[2] = dcval;  
    outptr[3] = dcval;  
    outptr[4] = dcval;  
    outptr[5] = dcval;  
    outptr[6] = dcval;  
    outptr[7] = dcval;

    wsptr += DCTSIZE;  
    /* advance pointer to  
    next row */  
    continue;
  }
#endif

/* Even part: reverse the even part of the forward
DCT. */

/* The rotator is sqrt(2)*c(-6). */
IOWR_JPEG_DATA(JPEG_BASE,0,wsptr[0]);
IOWR_JPEG_DATA(JPEG_BASE,2,wsptr[1]);
IOWR_JPEG_DATA(JPEG_BASE,4,wsptr[2]);
IOWR_JPEG_DATA(JPEG_BASE,6,wsptr[3]);
IOWR_JPEG_DATA(JPEG_BASE,8,wsptr[4]);
IOWR_JPEG_DATA(JPEG_BASE,10,wsptr[5]);
IOWR_JPEG_DATA(JPEG_BASE,12,wsptr[6]);
IOWR_JPEG_DATA(JPEG_BASE,14,wsptr[7]);

/*
for(counterint = 0; counterint < 10; counterint++) {
    cycleint = cycleint++;
}
*/

outptr[0]= range_limit[(int)DESCALE(IORD_JPEG_DATA
(JPEG_BASE,0),
    CONST_BITS+PASS1_BITS+3)&
RANGE_MASK];
outptr[1]= range_limit[(int)DESCALE(IORD_JPEG_DATA
(JPEG_BASE,1),
    CONST_BITS+PASS1_BITS+3)&
RANGE_MASK];
outptr[2]= range_limit[(int)DESCALE(IORD_JPEG_DATA
(JPEG_BASE,2),
    CONST_BITS+PASS1_BITS+3)&
RANGE_MASK];
outptr[3]= range_limit[(int)DESCALE(IORD_JPEG_DATA
(JPEG_BASE,3),
    CONST_BITS+PASS1_BITS+3)&
RANGE_MASK];
outptr[4]= range_limit[(int)DESCALE(IORD_JPEG_DATA
(JPEG_BASE,4),
    CONST_BITS+PASS1_BITS+3)&
RANGE_MASK];
outptr[5]= range_limit[(int)DESCALE(IORD_JPEG_DATA
(JPEG_BASE,5),
    CONST_BITS+PASS1_BITS+3)&
RANGE_MASK];
outptr[6]= range_limit[(int)DESCALE(IORD_JPEG_DATA
(JPEG_BASE,6),
    CONST_BITS+PASS1_BITS+3)&
RANGE_MASK];
outptr[7]= range_limit[(int)DESCALE(IORD_JPEG_DATA
(JPEG_BASE,7),
    CONST_BITS+PASS1_BITS+3)&
RANGE_MASK];

    wsptr += DCTSIZE;    /* advance pointer to next row */

#endif /* DCT_ISLOW_SUPPORTED */

alt_types.h
#ifndef __ALT_TYPES_H__
#define __ALT_TYPES_H__

/*******************************************************************************/
*/ License Agreement
*/
*
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*********************************************************
**********************/

/ *
* Don't declare these typedefs if this file is included by assembly source.
 */
#ifndef ALT_ASM_SRC
typedef signed char alt_8;
typedef unsigned char alt_u8;
typedef signed short alt_16;
typedef unsigned short alt_u16;
typedef signed long alt_32;
typedef unsigned long alt_u32;
typedef long long alt_64;
typedef unsigned long long alt_u64;
#endif

#define ALT_INLINE __inline__
#define ALT_ALWAYS_INLINE __attribute__((always_inline))
#define ALT_WEAK __attribute__((weak))
#endif /* __ALT_TYPES_H__ */

picturebrowser.c
#include <stdio.h>
#include <errno.h> //needed for errno
#include <string.h> //needed for strerror
#include <shimix_pio_button.h>

#include <fcntl.h>
#include <dirent.h>
#include <sys/stat.h>
#include <sys/types.h>

#define BUTTON_DEVICE "/dev/shimix"

static char* pics [100];
//pics = (char *) malloc(100);
static int count = 0;

void get_file_info(char *name, char *path){
    struct stat file_stats;
    if(stat(name, &file_stats) == -1){
        printf("\nFailed to access %s\n", name);
return;
}
printf("\nFile found!\n");
printf( " File name: %s\n", name);
printf( " Relative path: %s\n", path);
printf( " Protection mode: %d\n", file_stats.st_mode);
printf( " User id of owner: %d\n", file_stats.st_uid);
printf( " Group id of owner: %d\n", file_stats.st_gid);
printf( " Size in bytes: %d\n", file_stats.st_size);
if(count < 100){
    if(file_stats.st_size <= 20000){
        pics[count] = strdup(name);
        printf("Added pic[%d] = %s\n",count, name);
        count ++;
    }
    else{
        printf("File is too big. Skipping file...\n");
    }
}
if((file_stats.st_mode & S_IFMT) == S_IFDIR){
    printf("The file is a directory.\n\n");
}
}

void str_tolower(char *s)
{
    while(*s)
    {
        *s=tolower(*s);
        s++;
    }
}

int StartSearch(char *name, char *path, int
found_signal){

    DIR *dfd;
    struct dirent *dp;
    struct stat file_stat;

    if((dfd = opendir(path)) == NULL){
        printf("Directory [%s], failed to open.", path);
        return;
    }
    while (( dp = readdir(dfd)) != NULL){
        if(strcmp(dp->d_name, ".") == 0 || strcmp(dp->d_name, ".") == 0){
            continue; /*skipping itself and parent directories*/
        }
        char slash[2] = "\";

        char *path_cpy = (char *) malloc(sizeof(char)*strlen(path)+strlen(dp->d_name)+2);
        strcpy(path_cpy, path);

        char *d_nameCopy = (char *) malloc(sizeof(char)*strlen(dp->d_name)+2);
        strcpy(d_nameCopy, dp->d_name);

        char *combined = strcat(path_cpy, slash);
        char *full_name = strcat(combined, dp->d_name);

        if(stat(full_name, &file_stat) == -1){
            printf("\nFailed to access: %s\nSkipping...
", full_name);
            continue; /*skip bad file or directory*/
        }
        if((file_stat.st_mode & S_IFMT) == S_IFDIR){
            StartSearch(name, full_name, found_signal); /*recursive search*/
        }
    }
    str_tolower(d_nameCopy);
}
if(strstr(d_nameCopy, name)){
    get_file_info(full_name, path);
    found_signal = 1;
    //FILE FOUND!!!
}

free(path_cpy);
free(d_nameCopy);
}
closedir(dfd);
return found_signal;

int main(int argc, char *argv[])
{
    FILE * fButton;            //handle to button device
    char buf[1];              //read buffer to store value of button
    pushed when read from fButton
    int numBytesRead = 0;
    char keyInput = 0;
    unsigned int ioctlCmd;
    printf("Launching button reader v1.3\n");

    /* Establishing the root directory */
    char* initial_path = "home/";
    int found_signal = 0;
    char * jpg = ".jpeg";
    int find = StartSearch(jpg, initial_path, found_signal);
    jpg= ".jpg";
    find = StartSearch(jpg, initial_path, found_signal);

    char modprobe[28] = "modprobe\tshimix_pio_button";
    char makeDevice[29] = "mknod\t/dev/shimix\tc\t63\t0";
    //printf("mknod is ran\n\n");
    int x = system(modprobe);
    x = system(makeDevice);
fButton = fopen(BUTTON_DEVICE, "r"); //open button device for read-only
if (fButton==NULL) {
    printf("Error opening up %s\n", BUTTON_DEVICE);
    return -1;
}

ioctl(fileno(fButton), SBLD_IOCT_LEDBUTTONNUM, 1); // enable displaying button pushed
ioctl(fileno(fButton), SBLD_IOCT_LEDCOUNTER, 1); // enable button counters

printf("Entering main loop\n\n");

char command1[8] = "nano-X&";
char killall[20] = "killall\t-9\tnano-X";
// position of our cursor through the pics
int pos = 0;
//int j;
char andPersand[4] = "\t&";
char resize[6] = "\t12&";
char nxview[9] = "nxview\t";
char *command2;
short first_time = 0;

while (keyInput!='q' && keyInput!='Q') {
    printf("awaiting button: ");
    if ((numBytesRead=read(fileno(fButton), buf, sizeof(char), 0))<= 0) { //if no bytes read or error
        printf("Error reading %s\n", BUTTON_DEVICE);
    }
    else {
        x = system(killall);
        //j = sleep(1);
        if(first_time == 0){
            printf("executing command nano-X....\n");
        }
        x = system(command1);
        //j = sleep(1);
        command2 = (char *) malloc(sizeof(char)*strlen

(nxview));
    strcpy(command2, nxview);
    printf("%d %u
", buf[0], buf[0]);
    strcat(command2, pics[pos]);
    strcat(command2, andPersand);
    printf("executing %s ....\n", command2);
    x = system(command2);
    //j = sleep(1);
    free(command2);
    first_time = 1;
    }
    else{
      if (buf[0] == 2) {
        printf("executing command nano-X....\n");
        x = system(command1);
        //j = sleep(1);
        command2 = (char *) malloc(sizeof(char)*strlen(nxview));
        strcpy(command2, nxview);
        printf("%d %u
", buf[0], buf[0]);
        if (pos == count-1){
          pos = 0;
        }
        else{
          pos = pos + 1;
        }
        strcat(command2, pics[pos]);
        strcat(command2, andPersand);
        printf("executing %s ....\n", command2);
        x = system(command2);
        //j = sleep(1);
        free(command2);
      }
      else{
        if (buf[0] == 4) {
          printf("executing command nano-X....\n");
          x = system(command1);
          //j = sleep(1);
          command2 = (char *) malloc(sizeof(char)*strlen(nxview));
        }
strcpy(command2, nxview);
printf("%d %u\n", buf[0], buf[0]);
if (pos <= 0){
    pos = count - 1;
}
else{
    pos = pos - 1;
}
strcat(command2, pics[pos]);
strcat(command2, andPersand);
printf("executing %s ....\n",command2);
x = system(command2);
//j = sleep(1);
free(command2);
}
else{
    if (buf[0] == 8){
        printf("executing command nano-X....\n");
        x = system(command1);
        //j = sleep(1);
        command2 = (char *) malloc(sizeof(char)*strlen(nxview));
        strcpy(command2, nxview);
        printf("%d %u\n", buf[0], buf[0]);
        strcat(command2, pics[pos]);
        strcat(command2, resize);
        printf("executing %s ....\n",command2);
        x = system(command2);
        //j = sleep(1);
        free(command2);
    }
}

int i;

//printf("Press q to quit or any other key to continue reading buttons\n");
//keyInput = getchar();
for(i = 0; i < count; i++){
    free(pics[i]);
}

printf("Button Reader terminating\n");
}

rc
hostname uClinux
mount -t proc proc /proc
mount -t sysfs sysfs /sys
mount -t usbfs none /proc/bus/usb
mount -t vfat dev/sda1 mnt  # add this line
mkdir /var/tmp
mkdir /var/log
mkdir /var/run
mkdir /var/lock
mkdir /var/empty
ifconfig lo 127.0.0.1
route add -net 127.0.0.0 netmask 255.0.0.0 lo
# dhcpcd -p -a eth0 &
cat /etc/motd

nxview.c
/*
 * Copyright (c) 2000, 2001 Greg Haerr
<greg@censoft.com>
 *
 * nxview - Nano-X image viewer
 *
 * Autorecognizes and displays BMP, GIF, JPEG, PNG and XPM files
 */
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#define MWINCLUDECOLORS
#include "nano-X.h"
#include <errno.h> //needed for errno
#include <shimix_pio_button.h>
#include <fcntl.h>
#include <dirent.h>
#include <stat.h>
#include <types.h>

//#define BUTTON_DEVICE "/dev/shimix"
//static int count = 0;
/*

static char* pics [100];
static int count = 0;

void get_file_info(char *name, char *path){
    struct stat file_stats;
    if(stat(name, &file_stats) == -1){
        printf("Failed to access %s\n", name);
        return;
    }
    printf("File found!\n");
    printf( "    File name: %s\n", name);
    printf( "    Relative path: %s\n", path);
    printf( "    Protection mode: %d\n",
        file_stats.st_mode);
    printf( "    User id of owner: %d\n",
        file_stats.st_uid);
    printf( "    Group id of owner: %d\n",
        file_stats.st_gid);
    printf( "    Size in bytes: %d\n",
        file_stats.st_size);
    if(count < 100){
        if(file_stats.st_size <= 20000){
            pics[count]= strdup(name);
            printf("Added pic[%d] = %s\n",count, name);
            count ++;
        }
        else{
            printf("File is too big. Skipping file...\n");
        }
    }
}
if((file_stats.st_mode & S_IFMT) == S_IFDIR){
    printf("The file is a directory.\n\n");
}
*/
/**
int StartSearch(char *name, char *path, int
found_signal){

    DIR *dfd;
    struct dirent *dp;
    struct stat file_stat;

    if((dfd = opendir(path)) == NULL){
        printf("Directory [%s], failed to open.", path);
        return;
    }
    while (( dp = readdir(dfd)) != NULL){
        if(strcmp(dp->d_name, ".") == 0 || strcmp(dp->d_name, "..") == 0){
            continue; //skipping itself and parent directories//
        }
        char slash[2] = "\n"
        char *path_cpy = (char *) malloc(sizeof(char)*strlen(path)+strlen(dp->d_name)+2);
        strcpy(path_cpy, path);

        char *d_nameCopy = (char *) malloc(sizeof(char)*strlen(dp->d_name)+2);
        strcpy(d_nameCopy, dp->d_name);

        char *combined = strcat(path_cpy, slash);
        char *full_name = strcat(combined, dp->d_name);

        if(stat(full_name, &file_stat) == -1){
            printf("\nFailed to access: %s\nSkipping...\n", full_name);
            continue; //skip bad file or directory//
if((file_stat.st_mode & S_IFMT) == S_IFDIR){
    StartSearch(name, full_name, found_signal); // recursive search
}

str_tolower(d_nameCopy);

if(strstr(d_nameCopy, name)){
    get_file_info(full_name, path);
    found_signal = 1;
    //FILE FOUND!!
}

free(path_cpy);
free(d_nameCopy);
}
closedir(dfd);
return found_signal;
} /*

int main(int argc, char **argv)
{
    GR_IMAGE_ID image_id;
    GR_WINDOW_ID window_id;
    GR_GC_ID gc_id;
    GR_SIZE w = -1;
    GR_SIZE h = -1;
    GR_EVENT event;
    GR_SCREEN_INFO sinfo;
    GR_IMAGE_INFO info;
    char title[256];
    int pos = 0;
    int count = 10;
    /*
    FILE * fButton;          //handle to button device
    char buf[1];            //read buffer to store value of button
    pushed when read from fButton
    int numBytesRead = 0;
char keyInput = 0;
unsigned int ioctlCmd;
int pos = 0;
int count = 10;
printf("Launching button reader v1.3\n");

fButton = fopen(BUTTON_DEVICE, "r"); //open button device for read-only
if (fButton==NULL) {
    printf("Error opening up %s\n", BUTTON_DEVICE);
    return -1;
}

ioctl(fileno(fButton), SBLD_IOCT_LEDBUTTONNUM, 1); // enable displaying button pushed
ioctl(fileno(fButton), SBLD_IOCT_LEDCOUNTER, 1);   // enable button counters
*/

/* Establishing the root directory */
/* char* initial_path = "/home/";
int found_signal = 0;
char * jpg = ".jpeg";
int find = StartSearch(jpg, initial_path, found_signal);
jpg= ".jpg";
find = StartSearch(jpg, initial_path, found_signal);
int pos = 0;
int next_image = 0;
int first_time = 0;*/
//while(1) {

if (argc < 2) {
    printf("Usage: nxview <image file> [stretch]\n");
    exit(1);
}
if (GrOpen() < 0) {
    fprintf(stderr, "cannot open graphics\n");
    exit(1);
}

if (!(image_id = GrLoadImageFromFile(argv[1], 0))) {
    fprintf(stderr, "Can't load image file: %s\n", argv[1]);
    exit(1);
}

if(first_time == 0){
    GrGetImageInfo(image_id, &info);
    w = info.width;
    h = info.height;
}
first_time = 1;
/*
if(argc > 2) {
    // stretch to half screen size
    GrGetScreenInfo(&sinfo);
    w = sinfo.cols/2;
    h = sinfo.rows/2;
}
else {
    GrGetImageInfo(image_id, &info);
    w = info.width;
    h = info.height;
}

sprintf(title, "nxview %s", argv[1]);
window_id = GrNewWindowEx(GR_WM_PROPS_APPWINDOW, title,
GR_ROOT_WINDOW_ID, (640 - w)/2, (480 - h)/2, w, h, BLACK);

GrSelectEvents(window_id,
    GR_EVENT_MASK_CLOSE_REQ |
    GR_EVENT_MASK_EXPOSURE);

GrMapWindow(window_id);

gc_id = GrNewGC();

while (1) {
    GrGetNextEvent(&event);
    // if(next_image == 1) {
    //    event.type = GR_EVENT_TYPE_CLOSE_REQ;
    //} 
    switch(event.type) {
        case GR_EVENT_TYPE_CLOSE_REQ:
            GrDestroyWindow(window_id);
            GrDestroyGC(gc_id);
            GrFreeImage(image_id);
            GrClose();
            //break;
            exit(0);
            /* no return*/
        case GR_EVENT_TYPE_EXPOSURE:
            GrDrawImageToFit(window_id, gc_id, 0,0, w,h,
            image_id);
            break;
            }

        /*
        printf("awaiting button: ");
        if ((numBytesRead=read(fileno(fButton), buf, sizeof(char), 0))<=0) { //if no bytes read or error
         printf("Error reading %s\n", BUTTON_DEVICE);
    }
        else{

    
}
next_image = 1;
if (buf[0] == 2) {
    printf("%d %u\n", buf[0], buf[0]);
    //GrGetImageInfo(image_id, &info);
    //w = info.width;
    //h = info.height;
    if (pos == count-1){
        pos = 0;
    }
    else{
        pos = pos + 1;
    }
}
else{
    if (buf[0] == 4) {
        printf("%d %u\n", buf[0], buf[0]);
        //GrGetImageInfo(image_id, &info);
        //w = info.width;
        //h = info.height;
        if (pos <= 0){
            pos = count-1;
        }
        else{
            pos = pos - 1;
        }
    }
    else{
        if (buf[0] == 8){
            printf("%d %u\n", buf[0], buf[0]);
            //stretch to half screen size//
            //GrGetScreenInfo(&sinfo);
            //w = sinfo.cols/2;
            //h = sinfo.rows/2;
        }
    }
}
/*

//next_image = 0;
return 0;
} int i;
// for(i = 0; i < count; i++){
// free(pics[i]);
// }

//return 0;
//}
Chapter 9: License

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Version 2, June 1991

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Preamble

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