Data sheet for Sobel Edge Detection Core

Introduction:
The sharp change in image pixel intensity is called edge. The purpose of finding edges of an image is to significantly reduce the amount of data and to filter out useless information, while preserving the important structural properties of an image.

Sobel is gradient based edge detection algorithm. The gradient method looks the edges by finding maximum and minimum in the first derivative of the image. Sobel algorithm performs a 2-D spatial gradient measurement on an image. It uses a pair of 3X3 convolution masks, one estimating gradient in x-direction and other in y-direction. Then resultant magnitude is computed from the above two gradients.

Functional Description:
Sobel edge detection IP core accepts both gray scale image and color image. If it is color image, then it is sent through color space conversion block and the output of these converter, which is gray scale data is given to sobel x and y gradient convolution masks Gx and Gy. From the outputs of these convolution blocks resultant absolute magnitude is computed.
This magnitude is the final output of the Sobel edge detection output

-1	0	1
-2	0	2
-1	0	1

X-directional convolution mask Gx

1	2	1
0	0	0
-1	-2	-1

Y-directional convolution mask Gy

Features:
- High speed edge detection algorithm
- Compatible with all images resolutions
- Synchronous design
- Provision to change image frame sizes and Threshold of edges dynamically
- Available for Xilinx FPGA
- Core can be configured for any image frame size, edge Threshold and data width.
- Compatible, flexible and easy integration with other modules.

Block Diagram:

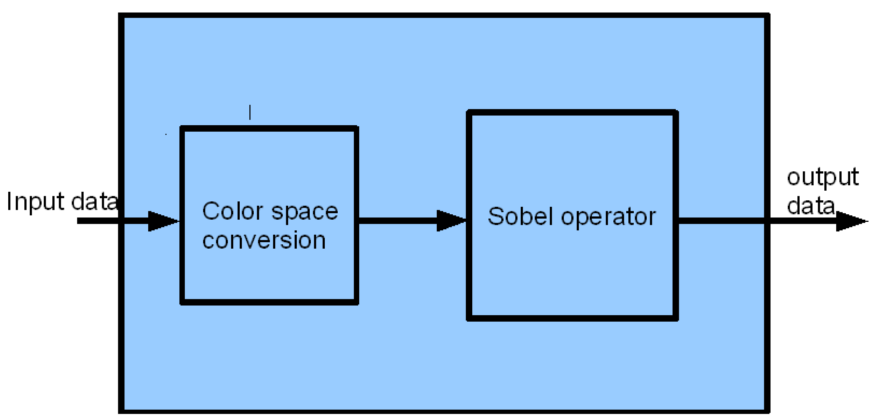

Figure 1: Sobel edge detector Block Diagram

Architecture Diagram:

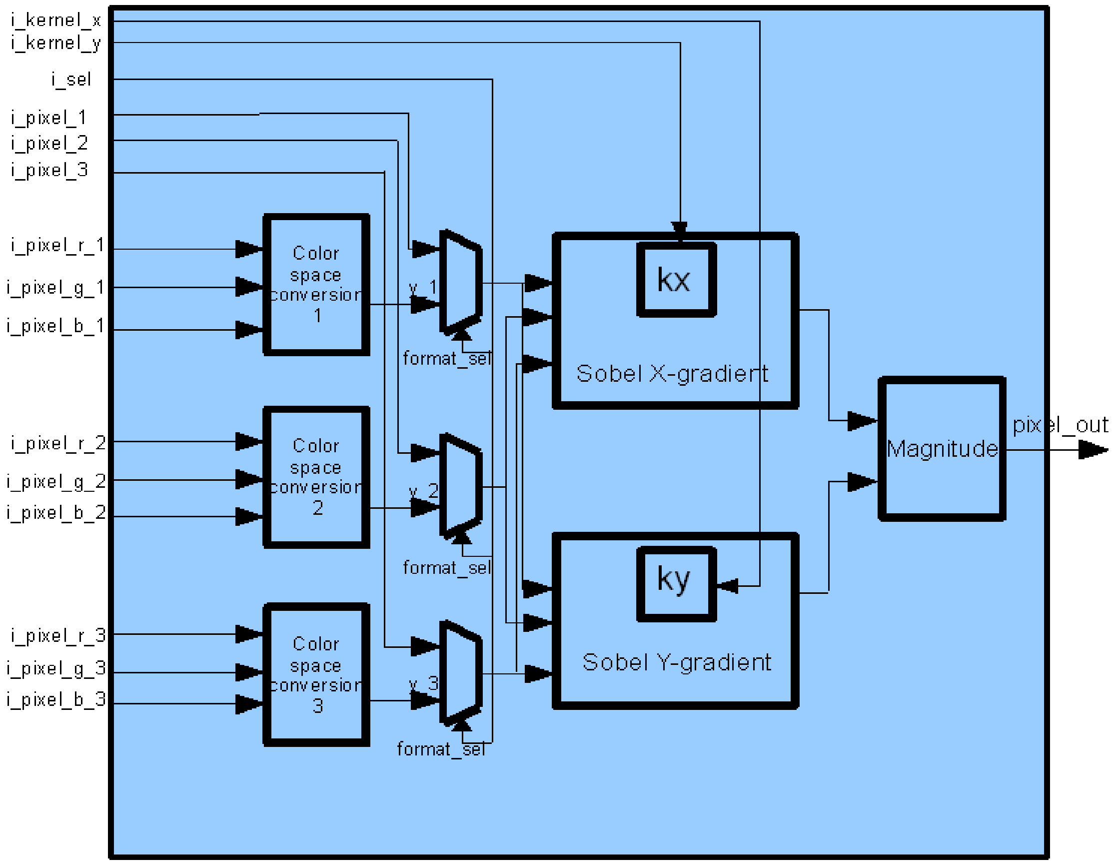

Figure 2: Sobel edge detector Architecture Diagram.

Description:

1. Figure.1 shows the block diagram of the Sobel edge detection core.
2. It consist mainly two building blocks. One is color space converter and other is Sobel operator block. Color space converter converts RGB input data into YcbCr format and out of that Luminance component (Y) is given as input to Sobel operator module. If the input is gray scale image then it can be fed directly to Sobel operator block.
3. Sobel operator block consist of two sub block for finding x-gradient and y-gradient of the input image and magnitude block which computes magnitude of the x-gradient and y-gradient pixels. Output of magnitude block goes as output data.
4. Figure.2 shows the architecture diagram of Sobel edge detection core. Since the order of the Sobel x-kernel and y-kernel is 3, three pixels per cycle are sent through input port.
5. There are two convolution modules named Sobel x-gradient and Sobel y-gradient, in which computation of x-gradient and y-gradient are done.
6. Input signal **format_sel** acts as select signal for selecting input either gray scale image or color image. Since three pixels per cycle have to be sent, here three color space converter (RGB to YcbCr) blocks are used.
7. Finally the outputs of all muxes (three outputs) are given to sobel x-gradient and sobel y-gradient modules.
8. These two modules compute x-gradient and y-gradient of the input image and the output is directly given to **Magnitude** block.
9. In Magnitude block, the absolute value of the x

and y gradients are computed as

10. g = sqrt (gx^2 + gy^2), where g is absolute value, gx and gy are x and y gradient components of input image.
11. The output of Magnitude block is given as output pixel data which represents edge image.
12. Table.1 shows all parameters used in the Sobel edge detection core.
13. Figure. 3 show the schematic symbol of the Sobel edge detection IP core.
14. Table.2 is signal definition table and shows all input and output signals which are used in Sobel edge detection IP core.
15. Table.3 shows the performance of the Sobel edge detection IP core on both virtex-4 and virtex-5 families.

Sobel edge detector Parameter Table

This table describes the general Sobel edge detector parameters:

Parameter	***Type***	***Description***
WL	Integer	Represents width of the each data symbol.
THRESHOLD	Integer	Represents the value of the threshold of the edges taken as reference for finding edges.

Table 1:Sobel edge detector Parameter table.

Schematic Symbol:

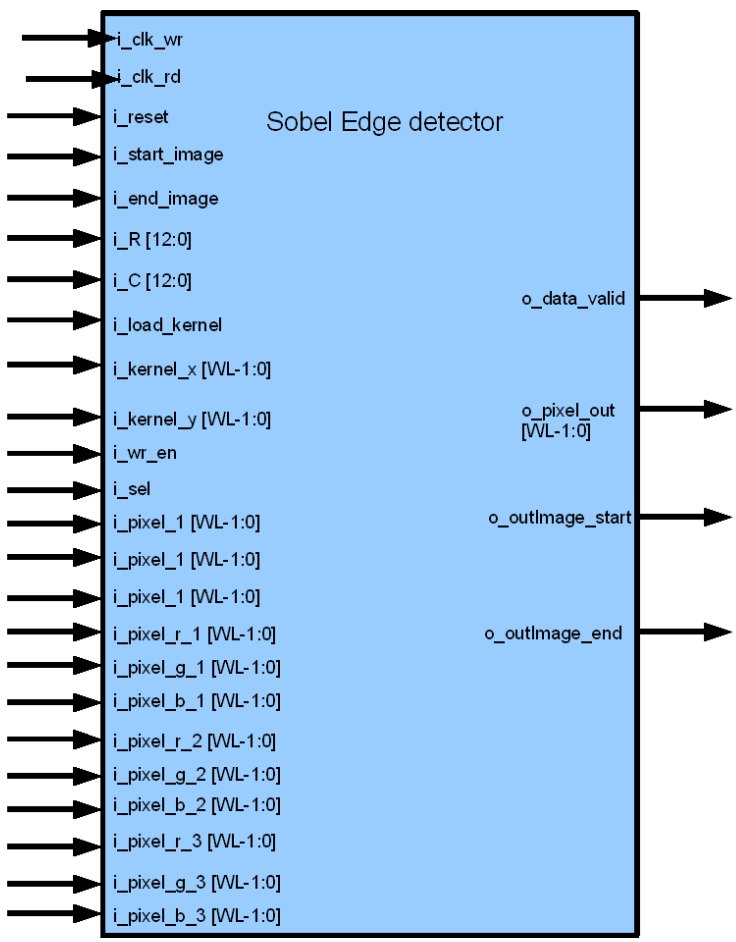

Figure 3: Sobel edge detector Schematic Symbol

Signal definition table:

Signal	*Direction*	*Data width*	*Description*
i_clk_rd	IN	1	This clock in sobel edge detector controls the logic from all FIFOs outputs onwards.
i_clk_wr	IN	1	All FIFOs writing is done with respect to this clock.
i_reset	IN	1	This signal resets the system whenever it is enabled and all counters, registers and state machines are initialized.
i_start_image	IN	1	This is single bit input signal which is enabled when first pixel of a new image frame. Otherwise disabled.
i_end_image	IN	1	This is single bit input signal which is enabled when last pixel of an current image frame. Otherwise disabled.
i_R	IN	13	This is 13 bit input port which specifies the number of rows of the image
i_C	IN	13	This is 13 bit input port which specifies the number of columns of the image
i_load_kernel	IN	1	This is single bit input port which is enabled when kernel data comes to the input port. And get disabled when there is no kernel data.
i_kernel_x	IN	WL	This is **WL** bit input port through which sobel x-gradient kernel elements will be loaded.
i_kernel_y	IN	WL	This is **WL** bit input port through which sobel y-gradient kernel elements will be loaded.
i_wr_en	IN	1	This is single bit input port which is when enabled, pixel data started writing into FIFOs. And when complete image is fed, this signal gets disabled.
i_sel	IN	1	This is single bit input signal which specifies whether gray scale data or color pixel data is presented at the input of the core.
i_pixel_1 i_pixel_2 i_pixel_3	IN	WL	This is WL bit width input port through which three pixels of gray scale image are sent to core.
i_pixel_r_1 i_pixel_g_1 i_pixel_b_1	IN	WL	This is WL bit input port for first pixel RGB values are send to core.
i_pixel_r_2 i_pixel_g_2 i_pixel_b_2	IN	WL	This is WL bit input port for second pixel RGB values are send to core
i_pixel_r_3 i_pixel_g_3 i_pixel_b_3	IN	WL	This is WL bit input port for third pixel RGB values are send to core.
o_data_valid	OUT	1	Asserted when data is valid on port o_pixel_out
o_pixel_out	OUT	WL	This is WL bit width output port through which sobel edge detector outputs edge founded pixel data.

Signal	*Direction*	*Data width*	*Description*
o_outImage_start	OUT	1	This signal is enabled when first pixel of resultant edge image comes out of the output port o_pixel_out.
o_outImage_end	OUT	1	This signal is enabled when last pixel of current image comes out of the output port o_pixel_out

Table 2: Sobel edge detector signal definition table.

Performance:

Device	Slice Count	Frequency (MHz)
Virtex-4	1804	230
Virtex-5	2113	250

Table 3: Sobel edge detection Core Performance table.

Verification:
The Sobel edge detection core module has been verified with following approaches:

- Exhaustive Functional/Timing simulation.
- Results compared with MATLAB functions and C source code functionality.

The Sobel edge detection core has been tested for both gray and color images. The following industry resolution images are tested on Sobel edge detection core.

- 256x256 resolution
- VGA resolution images (640 X 480).
- HD resolution images (1920 X 1080).
- 380 X 350 color image.

Deliverables:

- Verilog RTL source code
- The IP core test environment developed in verilog HDL (test benches).
- Synthesis and Simulation scripts.
- Detailed user documentation, including RTL source code documentation.

Applications:
The following are the applications of Edge detection in Image processing.

1. Image segmentation.
2. Feature detection.
3. Feature extraction.
4. Machine vision applications.
5. Inspection for missing parts.
6. Measurement of critical part dimensions.
7. Bio-medical image processing applications.
8. Adaptive surface smoothing.
9. Seismic image analysis.