Exploring the impact of Bit Rot

In an effort to understand the direct impact of "bit rot" on a file, and to inform potential research streams an image file was "attacked" by a script that sequentially flipped every bit, and tested the resulting image for (1) renderablity and (2) similarity to the source image.

Keywords:
Jpeg
Bit-Rot
RMSe
Render Test

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Summary

In an effort to understand the direct impact of “bit rot” on a file, and to inform potential research streams an image file was “attacked” by a script that sequentially flipped every bit, and tested the resulting image for (1) renderablity and (2) similarity to the source image.

Method

A python script was written that loops over a bitstream, locates each bit in order, inverts the bit, and saves the bitstream as a new image.

Each image is presented to imagemagik, which attempts the open the file.

If the file successfully opens, a root mean squared error (RMSe) value is calculated as a measure of difference between the original image and the new (bit flipped) image.

Example:

The following bitstream is presented to the script:

```
1111 0000 1010 0000
```

This results in the following bitstreams being created:

```
0111 0000 1010 0000
1011 0000 1010 0000
1101 0000 1010 0000
1110 0000 1010 0000
1111 1000 1010 0000
1111 0100 1010 0000
1111 0010 1010 0000
1111 0001 1010 0000
1111 0000 0010 0000
1111 0000 1110 0000
1111 0000 1000 0000
1111 0000 1011 0000
1111 0000 1010 1000
1111 0000 1010 0100
1111 0000 1010 0010
1111 0000 1010 0001
```

Comments

A demonstration test image was selected that contains a number of image features that are of interest to image research (e.g. gradual colour change / luma change, high frequency detail, blocks of solid colour etc.) and would specifically highlight errors in a jpeg compressed image. This source image was reduced to 180 x 120 pixels in size, which results in a 17,514 byte image. This is equal to 140,112 bits of data per image, which results in 140,112 new images being created. These 140,112 consume some 2.3 GB of storage.

This process is extremely resource intensive - On an i5 64-bit Ubuntu 12.04LTS install, with 16 Gb of RAM, writing to a 120Gb SSD HDD, the demonstration image run through took approximately 36 hours with ~60% of the processor time being consumed by the RMSe calculation.

As this test was undertaken as a proof of concept, very little analysis has been undertaken on the resulting images – there are some notable groups of error type, and some examples have been provided in this report. The results are provided for the interest of the reader.

Raw test data is available on request (filename, rendered? [Y|N], RMSe) for this test and some other jpg images used to test the workflow. Some resultant jpg files are available.

Exploring the RMSe values in the main result data show that most significant bits (MSB) being flipped frequently produce larger RMSe errors than the least most significant bits (LSB) from the same byte being flipped.

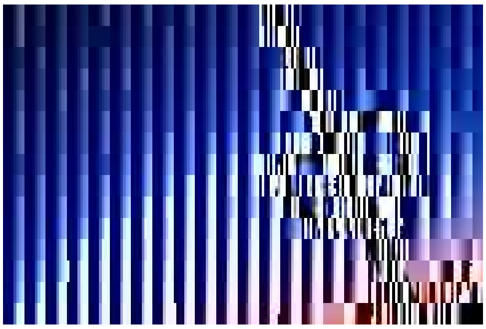
It is expected that this process could be (1) more efficiently coded, and (2) rolled out with other image types and further to other file types (the main factor would be renderance metrics, however, anything that is visually or sonically rendered RMSe remains a viable base measure).

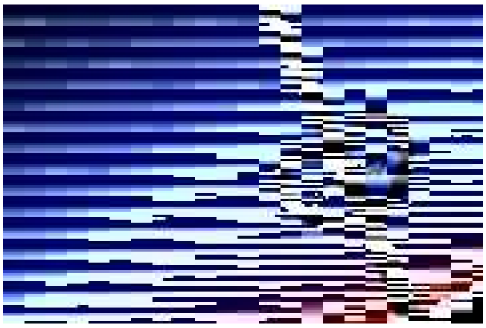
The next stage for the file type comparison would be to undertake the test on multiple files of the same type, and explore the resulting data looking for patterns in file structure that are particularly at risk. It is expected that different file types would have different bitstream locations that cause catastrophic file errors (for example, any bit flip attacks on the first or last 4 bytes of a PDF will result in a render fail as it damages the BOF or EOF marker the PDF renderer looks for.

Original Image:

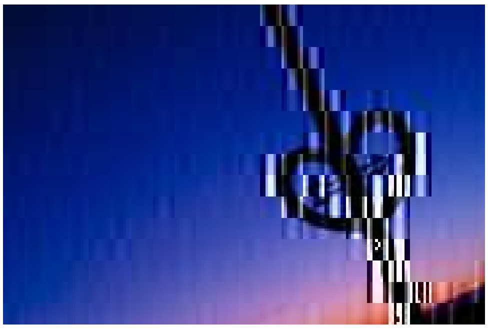
Specific examples of damage types:

Comb:



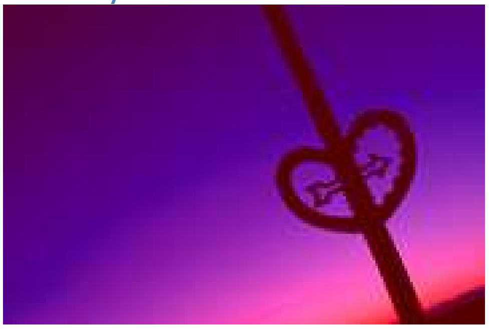


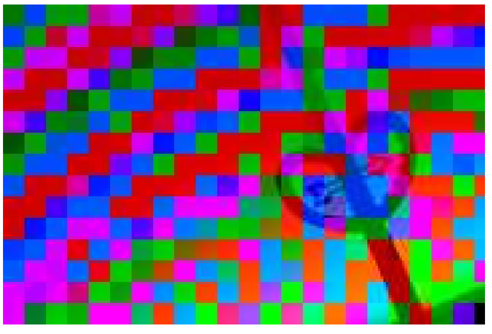
Detail:



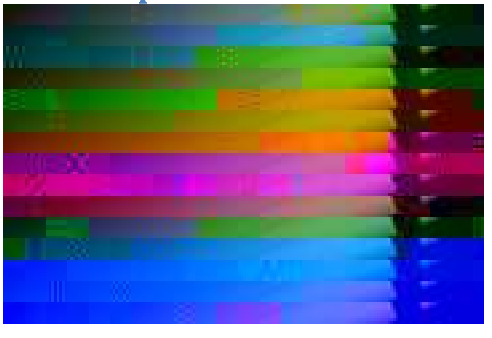
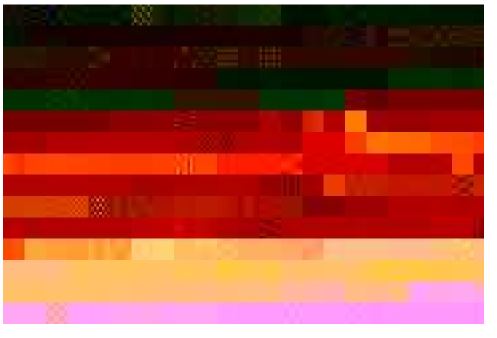
Block:

Colour/ tone:






Catastrophic

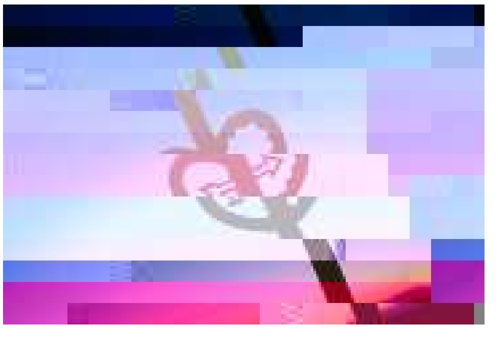
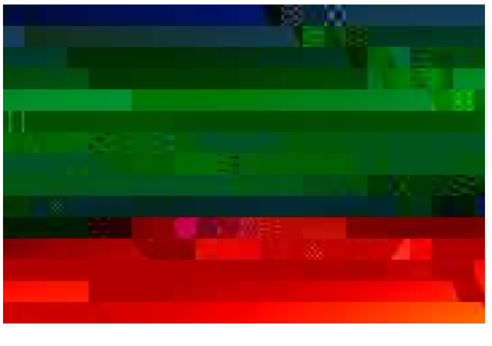
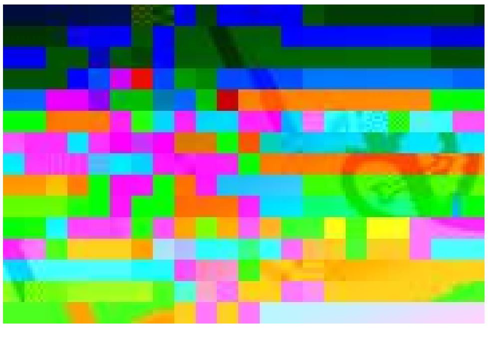




Image Dimensions:

Filename	W (pix)	H (pix)
163_0.jpg	180	32888
163_1.jpg	180	16504
163_2.jpg	180	8312
163_3.jpg	180	4216
163_4.jpg	180	2168
163_5.jpg	180	1144
163_6.jpg	180	632
163_7.jpg	180	376
164_0.jpg	180	248
164_1.jpg	180	56
164_2.jpg	180	88
164_3.jpg	180	104
164_4.jpg	180	112
164_5.jpg	180	124
164_6.jpg	180	122
164_7.jpg	180	121
163_0.jpg	32948	120
163_1.jpg	16564	120
163_2.jpg	8372	120
163_3.jpg	4276	120
163_4.jpg	2228	120
163_5.jpg	1204	120
163_6.jpg	692	120
163_7.jpg	436	120
164_0.jpg	52	120
164_1.jpg	244	120
164_2.jpg	148	120
164_3.jpg	164	120
164_4.jpg	188	120
164_5.jpg	176	120
164_6.jpg	182	120
164_7.jpg	181	120

This table shows the image dimensions for the 32 images that report a different image pixel size to the source image.

Catalogue of Errored images:

N.B The position of the flipped bit can be established from the file name:

XXX_N.jpg,

Where XXX is the byte location offset (decimal) in the bitstream

And N is the bit position in the stated byte of the flipped bit.

e.g. if the byte offset is 1,440

wellington.jpeg

	0	1	2	3
1,408	11111000	11100011	10111001	01100000
1,424	10001110	11110011	00010011	11011001
1,440	00111011	11001100	01001011	10100000
1,456	00100001	11000101	01101110	10110001
1,472	11000011	00111100	10010100	01001101
1,488	01101111	00000001	00101100	00100100
1,504	10110110	11001111	10011001	01110101
1,520	11110101	11101011	11000001	10111100
1,536	10011001	10000001	11011110	11101111
1,552	00110111	10011000	01100111	11011111

And the ‘bit to be flipped’ is the first ‘1’, the above byte would become:

wellington.jpeg*

	0	1	2	3
1,408	11111000	11100011	10111001	01100000
1,424	10001110	11110011	00010011	11011001
1,440	10111011	11001100	01001011	10100000
1,456	00100001	11000101	01101110	10110001
1,472	11000011	00111100	10010100	01001101
1,488	01101111	00000001	00101100	00100100
1,504	10110110	11001111	10011001	01110101
1,520	11110101	11101011	11000001	10111100
1,536	10011001	10000001	11011110	11101111
1,552	00110111	10011000	01100111	11011111

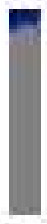
And the filename would become 1440_0.jpg

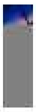
163_1.jpeg

163_2.jpeg

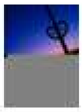
163_3.jpeg

163_4.jpeg


163_5.jpeg


163_6.jpeg


163_7.jpeg

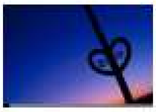

164_0.jpeg


164_1.jpeg

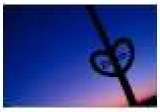

164_2.jpeg


164_3.jpeg


164_4.jpeg


164_5.jpeg


164_6.jpeg


164_7.jpeg

165_0.jpeg

165_1.jpeg

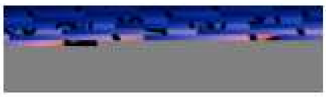
165_2.jpeg

165_3.jpeg

165_4.jpeg

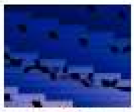

165_5.jpeg


165_6.jpeg

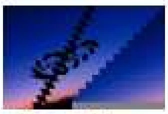

165_7.jpeg

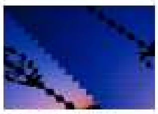

166_0.jpeg


166_1.jpeg


166_2.jpeg


166_3.jpeg

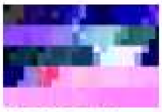

166_4.jpeg

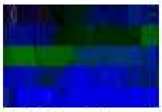

166_5.jpeg


166_6.jpeg

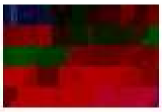

166_7.jpeg


169_2.jpeg

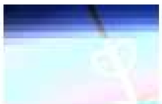

169_6.jpeg

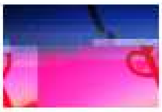

172_6.jpeg

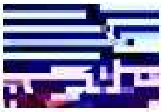

175_2.jpeg

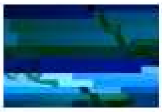

175_6.jpeg

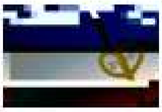

198_4.jpeg

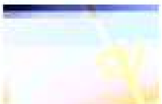

198_6.jpeg


198_7.jpeg


199_4.jpeg


199_5.jpeg


200_4.jpeg

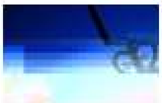

200_5.jpeg

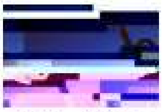

200_6.jpeg

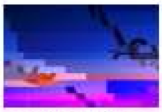

200_7.jpeg

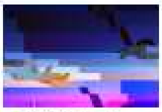

201_4.jpeg

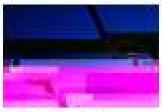

201_5.jpeg


201_6.jpeg


202_4.jpeg


202_5.jpeg


202_6.jpeg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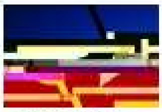
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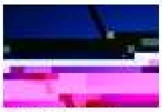
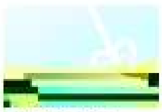
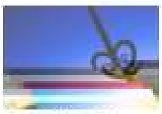

204_6.jpeg


205_4.jpeg


205_5.jpeg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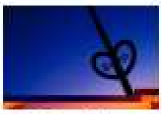
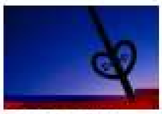
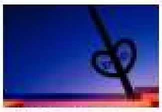

206_4.jpeg

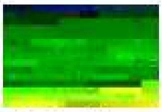

206_5.jpeg


206_6.jpeg


206_7.jpeg


208_4.jpeg


230_0.jpeg


230_1.jpeg


230_2.jpeg


230_3.jpeg

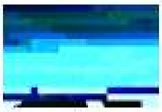

230_4.jpeg


230_5.jpeg


230_6.jpeg


230_7.jpeg


231_0.jpeg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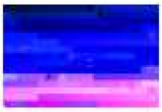
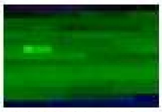

231_2.jpeg

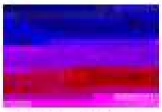

231_3.jpeg


231_4.jpeg


231_5.jpeg


231_6.jpeg


231_7.jpeg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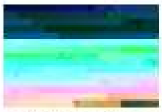

232_1.jpeg

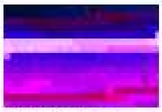

232_2.jpeg

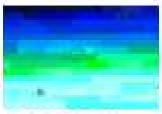

232_3.jpeg


232_4.jpeg


232_5.jpeg


232_6.jpeg


232_7.jpeg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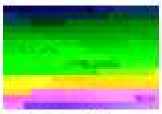
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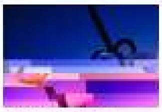
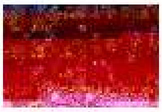
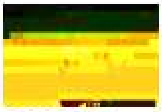
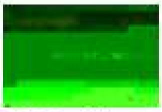
233_2.jpeg


233_3.jpeg

233_4.jpeg

233_5.jpeg

233_6.jpeg

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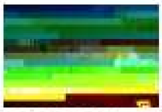
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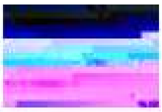
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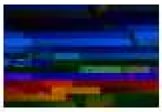
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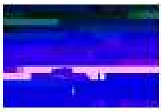
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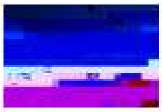
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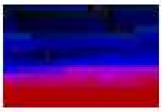
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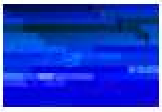
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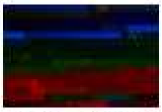
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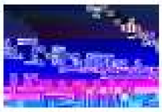
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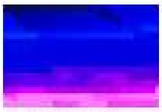
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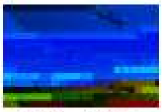
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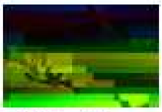
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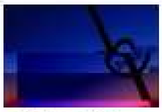
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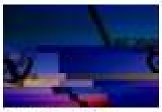
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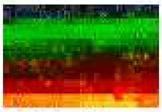
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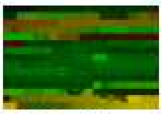
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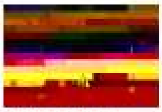
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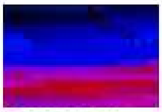
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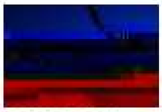
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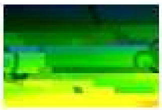
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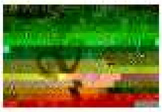
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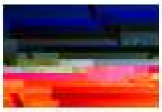
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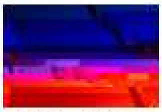
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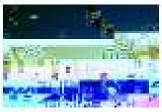
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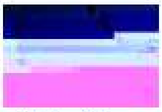
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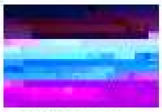
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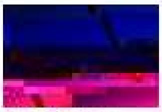
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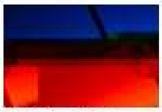
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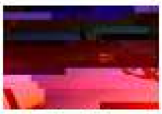
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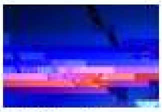
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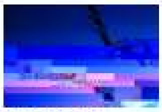
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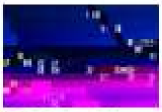
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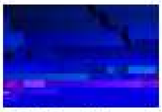
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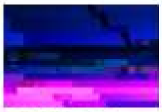
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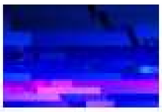
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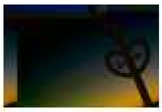
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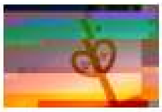
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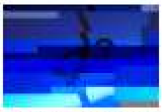
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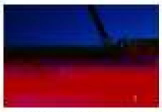
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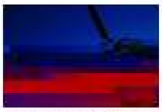
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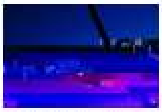
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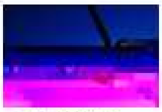
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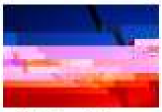
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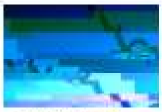
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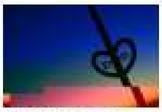
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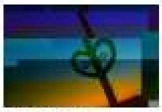
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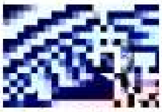
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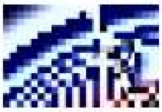
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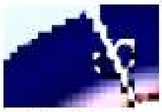
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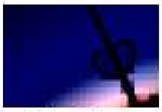
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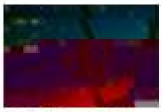
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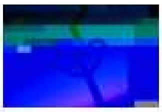
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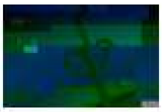
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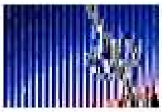
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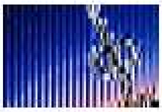
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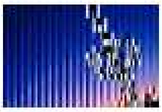
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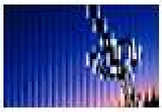
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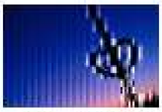
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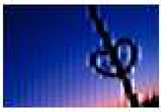
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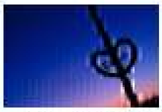
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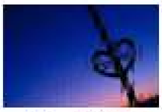
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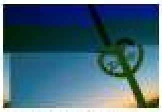
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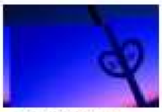
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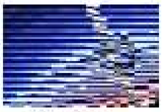
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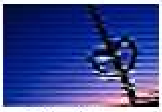
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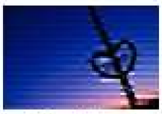
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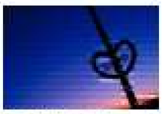
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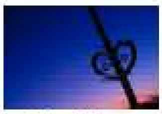
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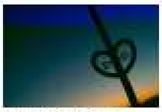
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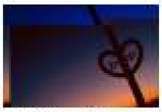
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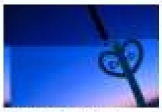
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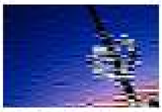
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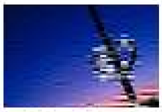
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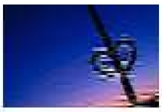
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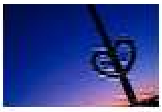
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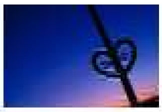
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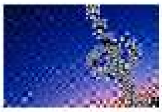
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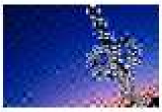
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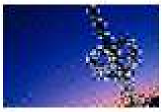
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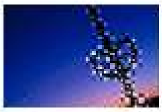
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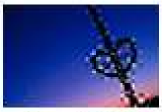
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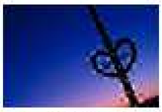
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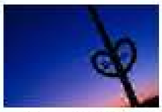
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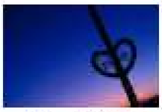
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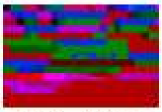
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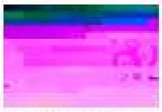
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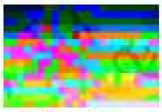
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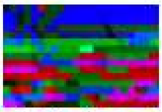
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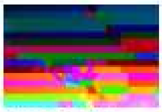
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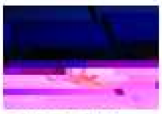
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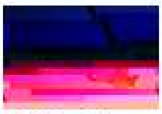
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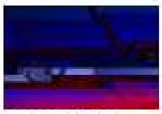
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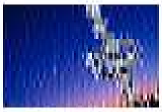
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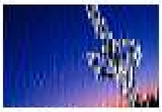
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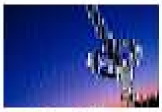
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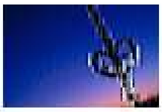
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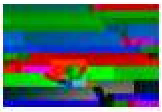
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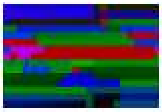
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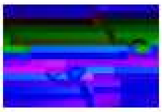
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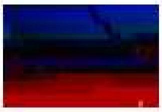
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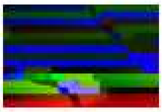
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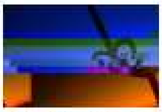
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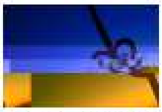
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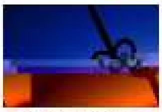
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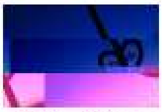
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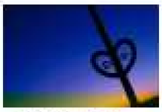
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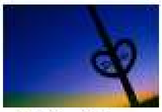
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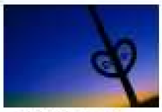
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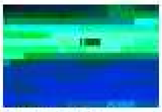
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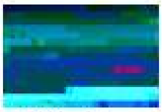
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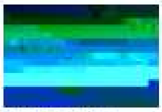
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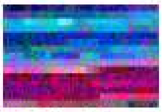
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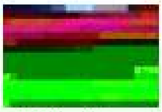
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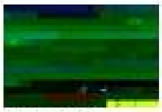
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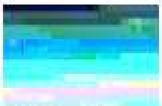
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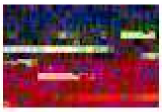
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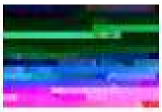
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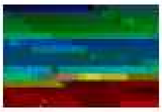
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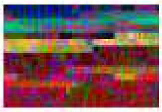
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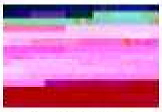
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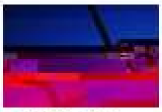
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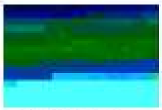
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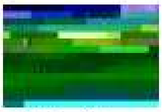
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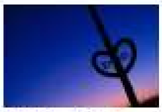
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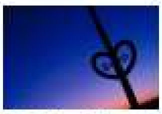
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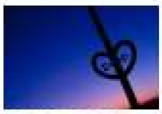
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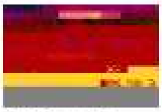
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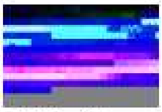
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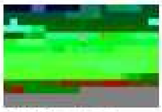
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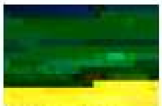
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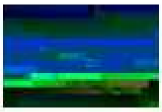
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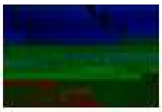
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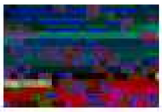
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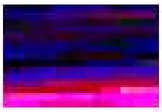
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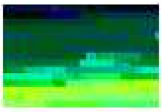
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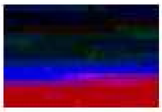
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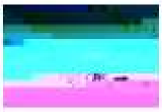
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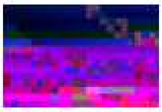
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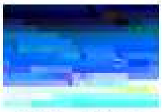
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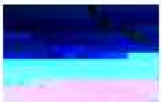
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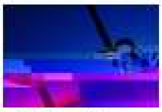
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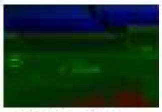
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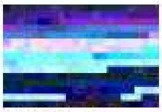
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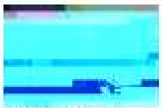
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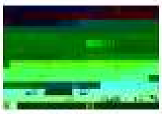
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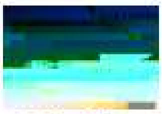
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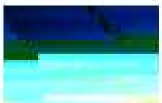
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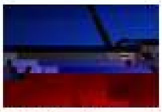
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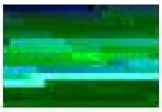
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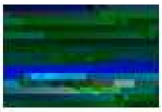
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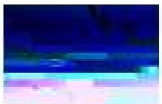
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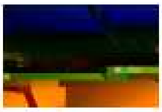
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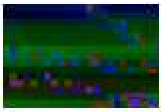
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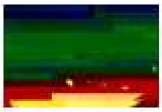
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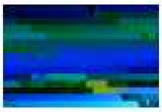
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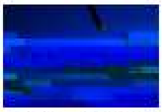
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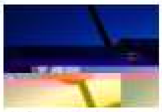
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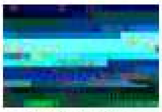
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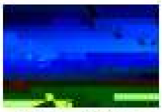
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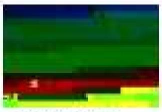
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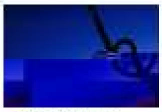
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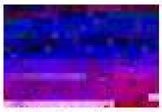
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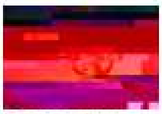
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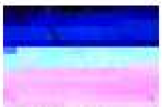
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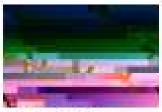
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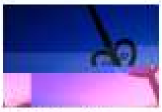
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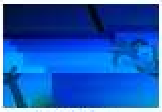
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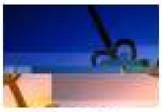
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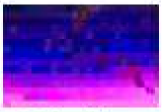
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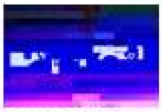
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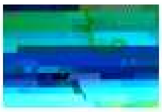
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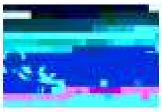
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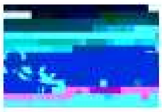
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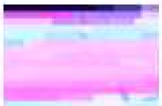
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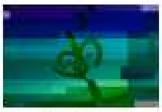
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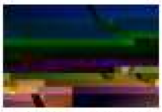
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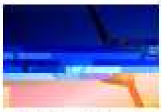
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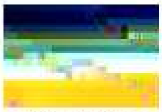
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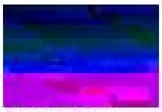
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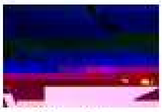
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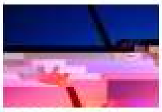
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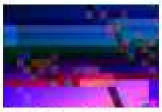
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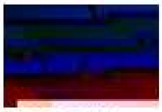
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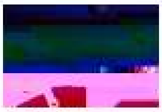
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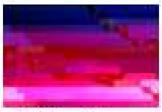
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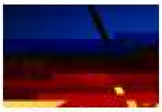
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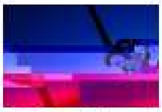
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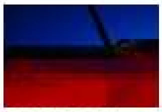
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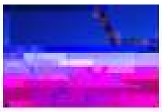
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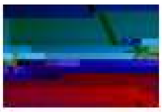
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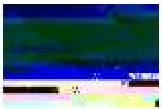
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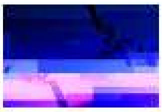
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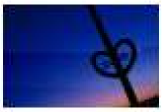
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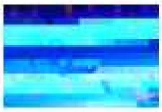
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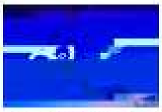
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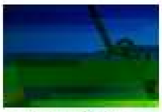
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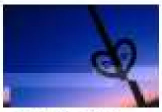
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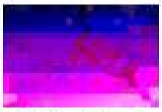
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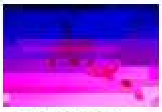
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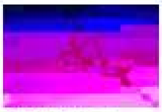
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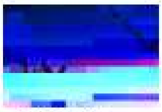
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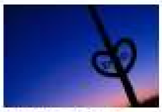
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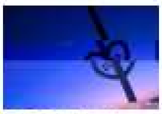
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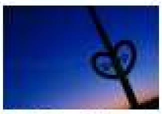
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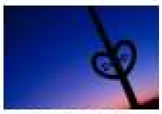
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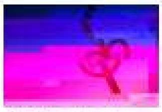
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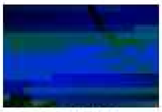
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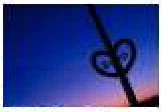
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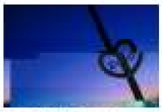
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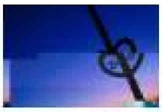
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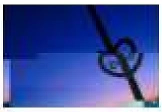
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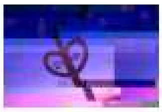
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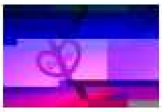
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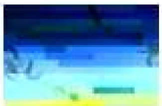
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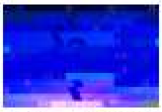
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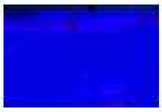
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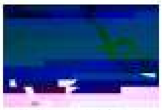
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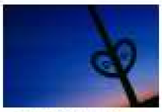
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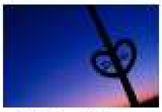
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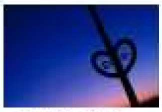
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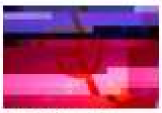
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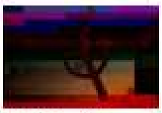
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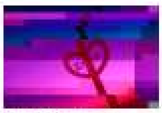
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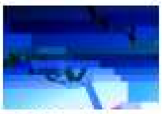
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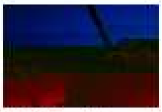
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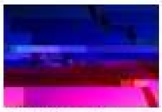
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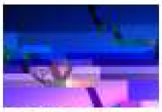
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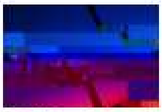
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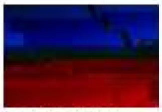
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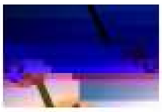
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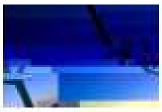
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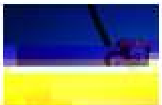
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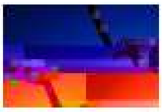
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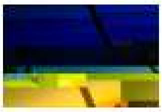
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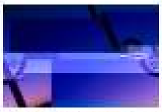
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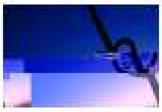
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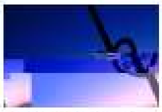
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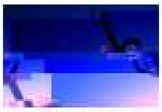
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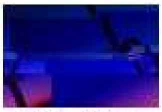
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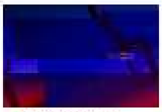
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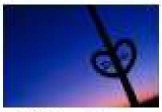
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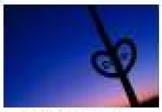
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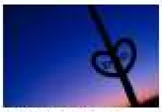
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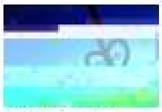
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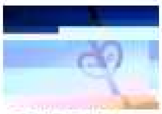
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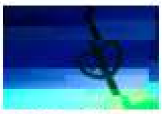
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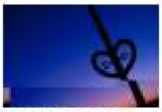
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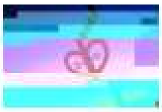
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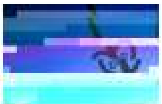
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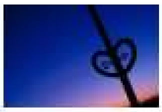
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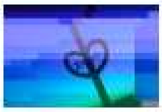
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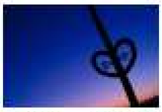
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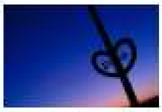
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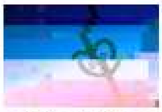
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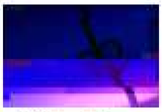
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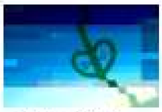
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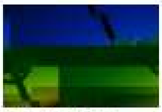
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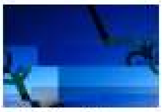
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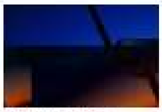
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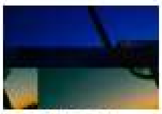
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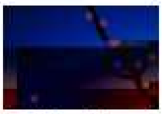
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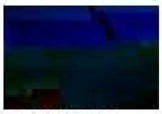
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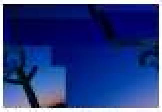
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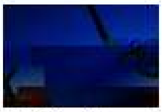
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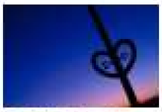
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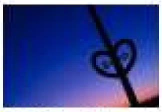
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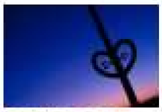
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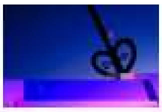
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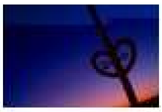
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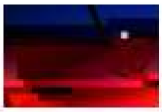
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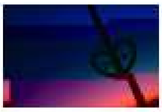
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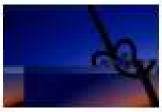
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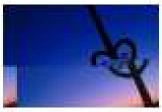
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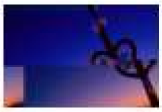
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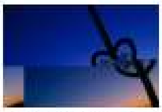
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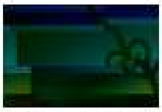
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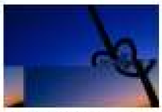
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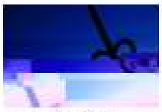
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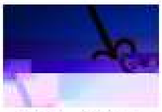
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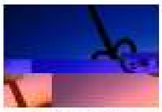
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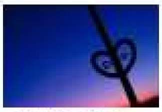
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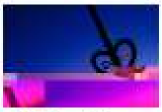
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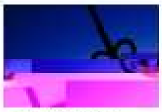
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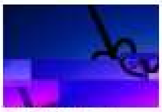
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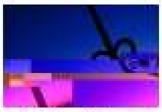
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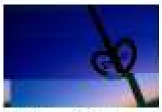
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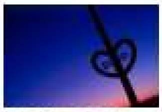
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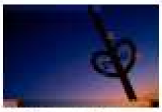
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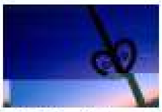
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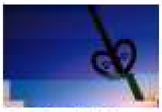
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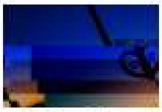
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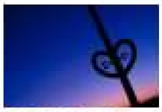
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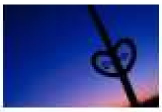
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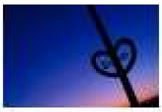
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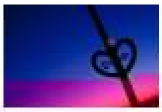
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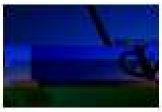
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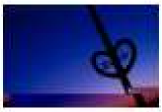
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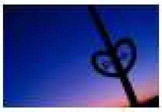
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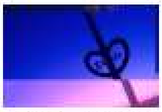
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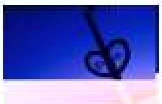
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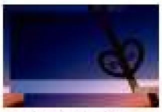
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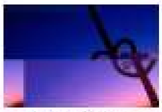
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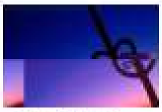
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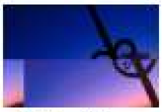
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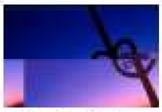
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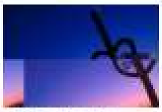
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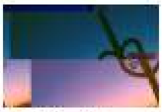
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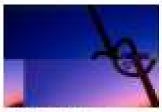
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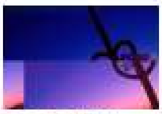
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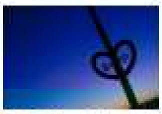
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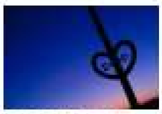
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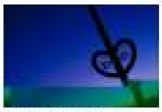
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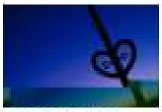
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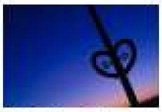
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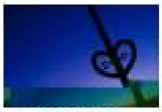
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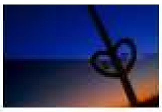
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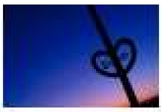
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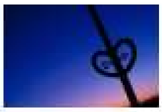
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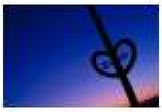
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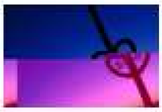
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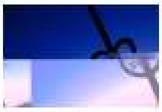
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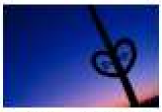
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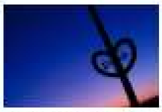
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367_6.jpeg


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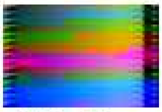
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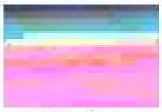
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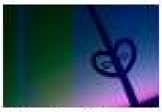
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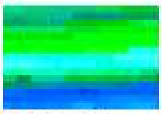
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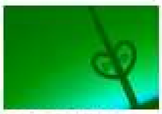
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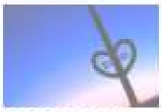
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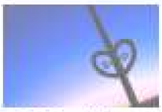
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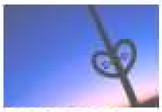
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388_3.jpeg

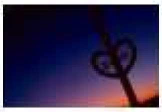

388_5.jpeg


397_2.jpeg


397_3.jpeg


397_4.jpeg


398_0.jpeg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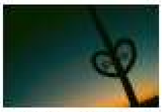
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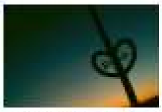
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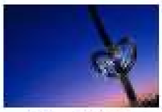
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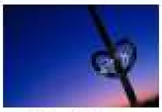
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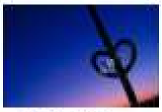
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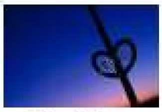
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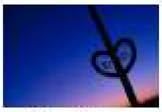
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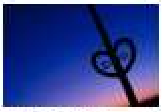
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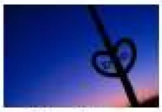
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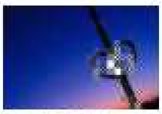
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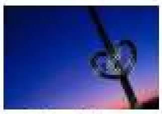
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64_3.jpeg


64_4.jpeg


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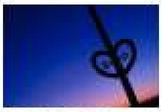
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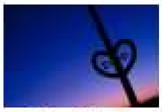
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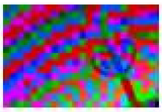
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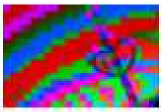
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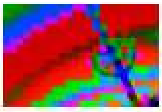
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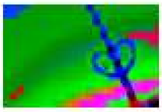
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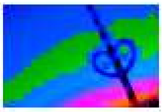
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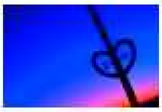
94_5.jpeg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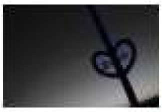
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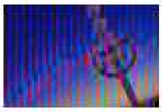
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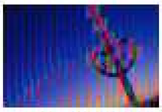
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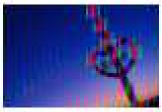
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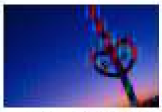
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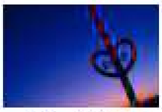
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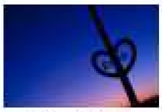
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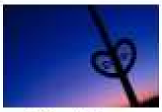
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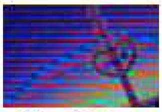
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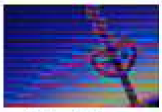
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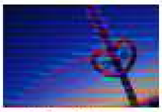
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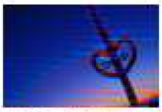
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