




Tecniche per il controllo del bit/rate per immagini fotografiche e video

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Agenda Digital Still Camera Program

- Introduction
- Still images
- Video sequences

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Goal

Digital Still Camera Program

To ensure a file size as close as possible to a target value

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Digital Still/Moving Camera

Digital Still Camera Program

```
graph LR; Sens[Sens] --> PreProc[Pre proc]; PreProc --> ColorInterp[Color interpolation]; PreProc --> DRAM[DRAM]; ColorInterp --> RGB[RGB]; ColorInterp --> YCrCb[Color interpolation]; YCrCb --> RGBtoYCrCb[RGB->YCrCb Subsamp.]; RGBtoYCrCb --> JPEG[JPEG MPEG]; JPEG --> StillVideo[Still / video image];
```

The diagram illustrates the processing pipeline for a digital still/moving camera. It starts with a sensor (Sens) that outputs a Bayer pattern. This pattern goes through a pre-processing (Pre proc) stage, which also interacts with DRAM. The output of the pre-processing is then processed by a color interpolation block, which produces an RGB image. This RGB image is then processed by an RGB-to-YCrCb subsampling block, which produces a YCrCb image. Finally, the YCrCb image is processed by a JPEG/MPEG block, which produces a still or video image.

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Digital Still Camera Program

Memory requirements (still)

Sensor dim (pixel)	Size (uncompressed)
307200 (VGA)	900KB
1.3 Mpel	3.7MB
2.1 Mpel	6MB
5 Mpel	14.3MB
8 Mpel	22.8 MB

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Digital Still Camera Program

Memory requirements (video)

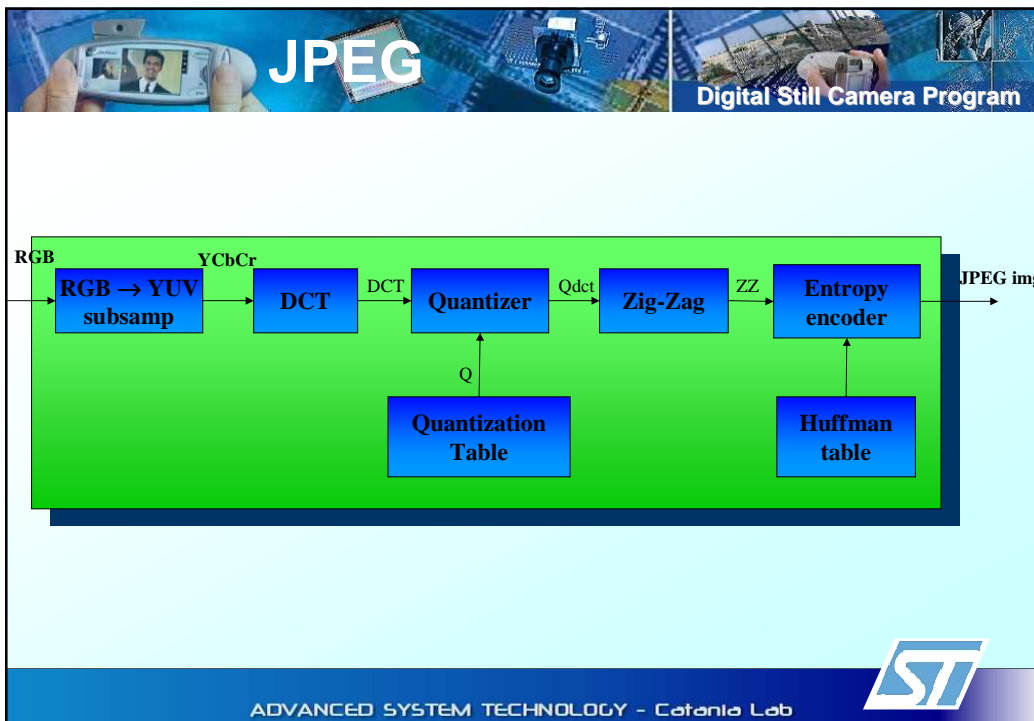
Sensor dim (pixel)	Size (bytes) (15 fps)
176x144 (QCIF)	1 MB/s
352x288 (CIF)	4.3 MB/s
640x480 (VGA)	13.2 MB/s
1280x720 (HDTV)	39.5 MB/s
1920x1080 (Full HDTV)	89 MB/s

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Digital Still Camera Program


JPEG

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Which phases? Digital Still Camera Program


- ✗ **Color Transform (RGB → YCbCr)**
- ✗ **Subsampling**
- ✗ **Discrete Cosine Transform**
- ✓ **Quantization**
- ✗ **DC Coefficient Encoding**
- ✗ **Zig-zag ordering of AC Coefficients**
- ✓ **Entropy Coding**




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Which phases? Digital Still Camera Program

- **Quantization phase**
Modifying the Q-tables the file size can be varied.
- **Huffman phase**
Optimizing the Huffman tables the file size decrease. It is too expensive!



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How to measure


Digital Still Camera Program

The compression factor control algorithms can be compared through three different aspects:

- Precision
- Image quality
- Speed
- Resources (Computational cost, power consumption, ...)




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JPEG CF-CTRL

Digital Still Camera Program

- To find the Q-tables allowing to obtain the required bit/rate.
 - 1) Optimize each coefficient separately in order to obtain the best quality. It is too expensive.
 - 2) Modify a fixed Q-table according to a multiplier value, called *Gain*



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JPEG CF-CTRL

Digital Still Camera Program

$$\hat{Q} = G \cdot Q$$

JPEG block

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Bit rate vs Gain

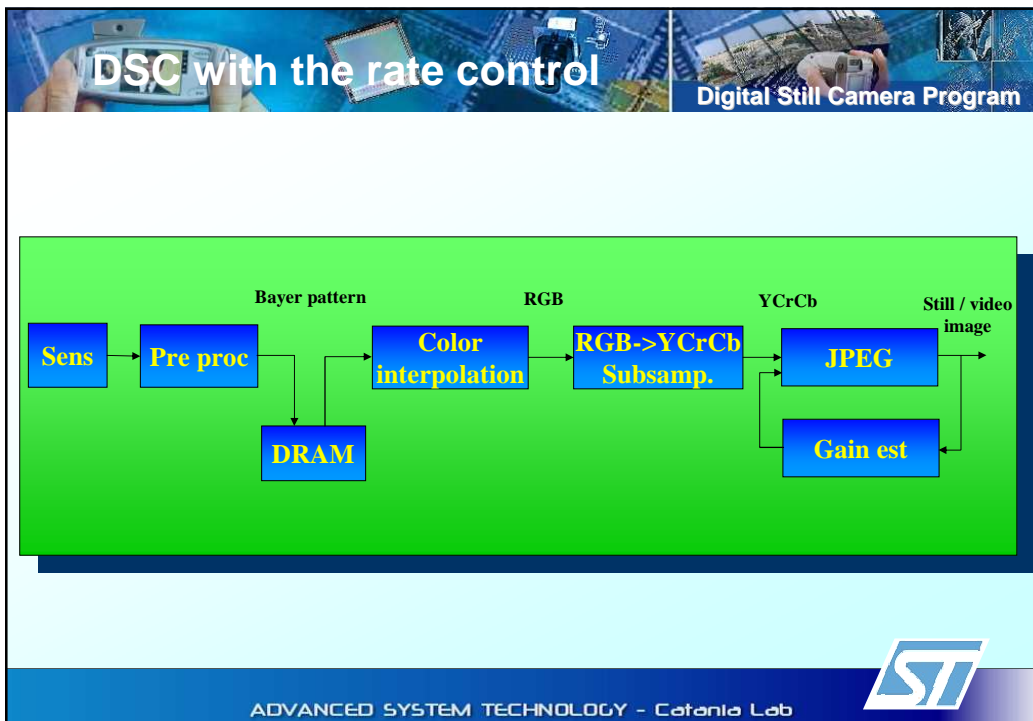
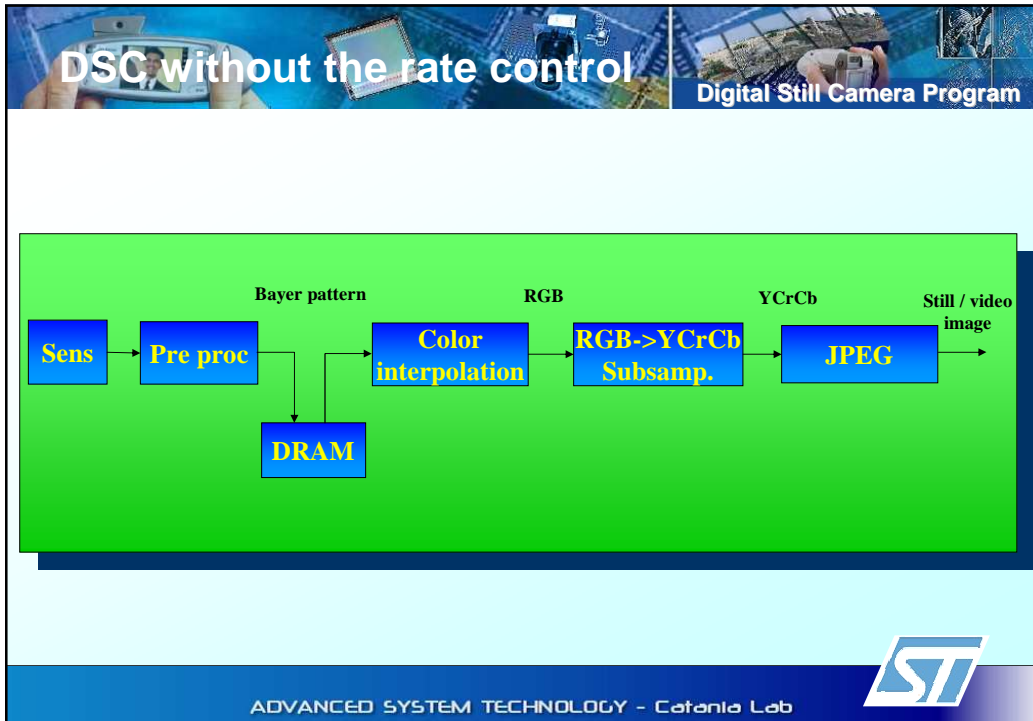
Digital Still Camera Program


bit per pixel vs Gain value

Gain	Red Curve (bit/pel)	Blue Curve (bit/pel)	Green Curve (bit/pel)
0.0	7.5	6.5	5.5
0.1	4.5	3.5	2.5
0.2	3.0	2.5	1.8
0.3	2.5	2.0	1.5
0.4	2.2	1.8	1.3
0.5	2.0	1.6	1.2
0.6	1.8	1.5	1.1
0.7	1.6	1.4	1.0
0.8	1.5	1.3	0.9
0.9	1.4	1.2	0.8

- The bitpel varies discontinuously according to G


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Infinite number of cycles

- Really high precision
- Slow
- High power consumption




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Algorithms

- Constant precision
- Constant cycles count




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Constant precision algorithm

Digital Still Camera Program

- The cycle is repeated until the bit/rate is out of the prefixed precision range
- Main features:
 - 😊 The precision is always the required value
 - 😞 The time is unpredictable
 - 😞 The power consumption is unpredictable


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Constant cycles number

Digital Still Camera Program

- The cycle is repeated n-times
- Main features:
 - 😞 The precision is unpredictable (statistical range is retrieved)
 - 😊 The time is fixed
 - 😊 The power consumption is fixed

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Constant precision pseudo code Digital Still Camera Program

```
Init (threshold, G, target)
repeat
    bitrate = JPEGcompress(img, G);
    G = modifyG(bitrate, target, G);
until (abs(bitrate-target)<threshold)
```

Where:

- img** is the image;
- G** is the current gain value;
- target** is the target bit rate;
- threshold** is the required precision;
- init()** set the initial values;
- JPEGcompress()** is a function that compress the image and return the bit count;
- modifyG()** is the core of the rate control and modify the Gain value; according to the current results.

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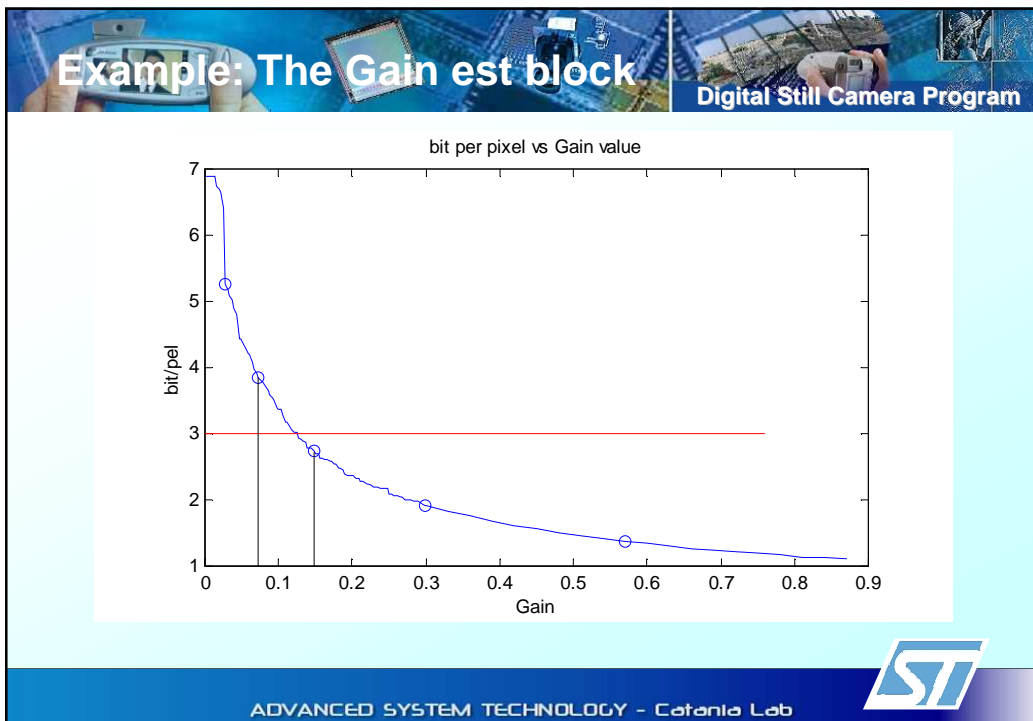
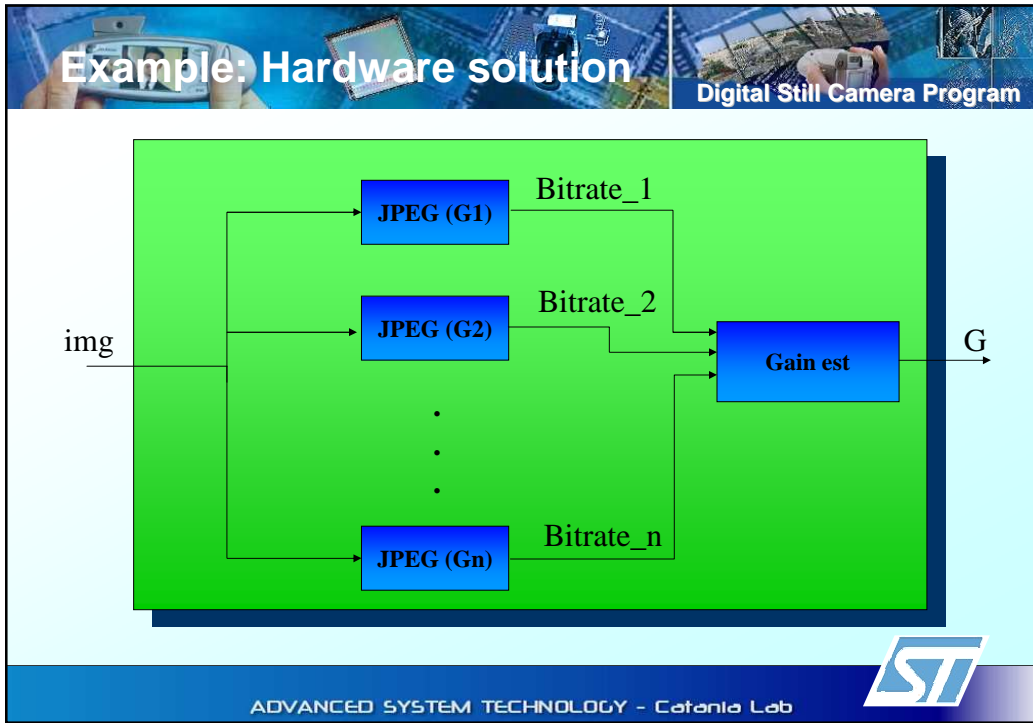
Constant cycles pseudo code Digital Still Camera Program

```
Init (ncycles, G, target)
for (i =1; i < ncycles; i ++)
{
    bitrate = JPEGcompress(img, G);
    G = modifyG(bitrate, target, G);
}
```

Where:

- img** is the image;
- G** is the current gain value;
- target** is the target bit rate;
- threshold** is the required precision;
- init()** set the initial values;
- JPEGcompress()** compress the image and return the bit count;
- modifyG()** is the core of the rate control and modify the Gain value according to the current results.

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Digital Still Camera Program

MPEG 4

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MPEG4 – SP@L3 Digital Still Camera Program

The diagram illustrates the MPEG4 SP@L3 encoding process. It starts with 'UNCOMPRESSED FRAMES' entering a 'MOTION ESTIMATOR'. The output of the motion estimator is added to the original frames at a summing junction. This result then goes through a 'DCT' block, followed by a 'Q' (quantization) block. The 'RATE CONTROL ALGORITHM' receives input from the 'Q' block and provides feedback to the 'MOTION ESTIMATOR' and the 'Q' block. The output of the 'Q' block goes through 'AC/DC pred.' and 'VLC' blocks. The output of the 'VLC' block goes to a 'MUX' block, which then feeds into a 'BUFFER' block, resulting in a 'COMPRESSED BITSTREAM'. A 'FRAMES STORE' block receives 'VECTORS MODES' and provides input to the 'MOTION ESTIMATOR'. The 'FRAMES STORE' also receives input from the 'I-DCT' block and provides output to the 'I-Q' block. The 'I-Q' block outputs to the 'I-DCT' block, which then feeds back into the 'MOTION ESTIMATOR' at a summing junction.

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Motion estimator

Digital Still Camera Program

Previous I or P frame

Current frame

- Maps the current MB in the previous and the next (B frame only) encoded frame.
- Gives the Motion Vector (MV)

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DCT / I-DCT

Digital Still Camera Program

- Perform the Discrete Cosine Transform and the inverse transformation (identical to JPEG)

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Q / I-Q

Digital Still Camera Program

- Perform the quantization and the inverse quantization
- Two different quantization can be performed:
 - 1) Using a weighting matrix ;
 - 2) Using a fixed quantization value.

Both the methods allow to modulate the quantization through a Quantization Parameter (QP). It can be modified at MB level.

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DC prediction

Digital Still Camera Program

The diagram illustrates DC prediction for a macroblock. It shows two rows of blocks. The top row contains blocks B, C, and D. The bottom row contains blocks A, X, and Y. A dashed box encloses blocks A, X, and Y, with the label 'Macroblock' to its right. Arrows indicate prediction paths: from B to C, from C to D, and from A to X. The word 'or' is placed between the arrows from C to D and from A to X, indicating alternative prediction sources.

- The DC coeff is always predicted by the DC in the previous block or in the block above.

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AC prediction

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- The first line's AC coeffs or the first column can be predicted by the same block used for the DC prediction

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VLC

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- A Run-Length / Variable Length encoder is used to compress the quantized data.
- The Huffman codes are imposed by the standard

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Which phases?

Digital Still Camera Program

- ✗ Motion estimation
- ✗ Discrete Cosine Transform
- ✓ Quantization
- ✗ DC – AC prediction
- ✗ Entropy Coding

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HOW

Digital Still Camera Program

The rate control can be performed modifying the quantization parameter (QP)

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Video rate control algorithms

Digital Still Camera Program

Two different kind of algorithms are developed:

- 1) VBR (variable bit rate)
The picture quality is important
- 2) CBR (constant bit rate)
The rate is important

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VBR

Digital Still Camera Program


Main features:

- The QP is modified at frame level
- A constant quality picture is obtained
- The quality between adjacent frames is similar
- The rate is not ensured at frame level

Applications

- Short video messages
- Storable video

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CBR


Digital Still Camera Program


Main features:

- The QP is modified at macroblock level
- A very hard rate control is performed
- A variable quality picture is obtained

Applications

- Real time applications (video conferences, ...)

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VBV - Video Buffer Verifier

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- The encoder/decoder have limited buffers for the data
- It allows to verify that the memory required in a decoder is less than the stated buffer size
- It allows to control the buffer fullness in a real time application

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