UNM Electrical & Computer Engineering
ivPCL
Image and video Processing and Communications Laboratory

DYNAMIC MULTIOBJECTIVE OPTIMIZATION MANAGEMENT OF THE ENERGY-PERFORMANCE-ACCURACY SPACE FOR SEPARABLE 2-D COMPLEX FILTERS

ABSTRACT

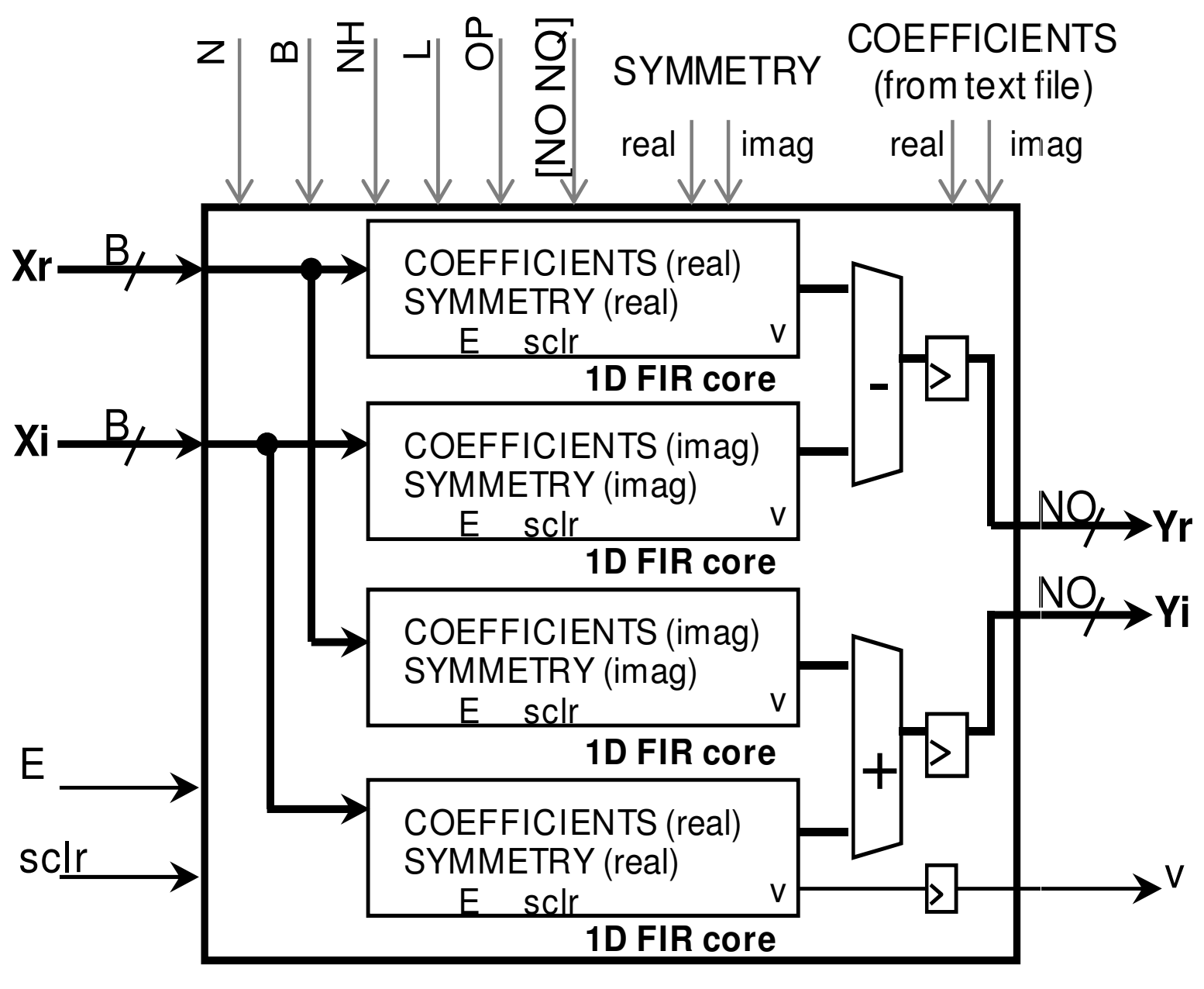
We present a dynamic framework for 2D complex filter implementation that is based on a multi-objective optimization scheme that generates Pareto-optimal realizations from the Energy-Performance-Accuracy (EPA) space.

The EPA space is created by evaluating the 2D complex filter realizations in terms of their required energy, accuracy, and performance. Dynamic EPA management, carried out via Dynamic Partial Reconfiguration (DPR) and Dynamic Frequency Control, then consists on selecting Pareto-optimal realizations that meet time-varying EPA requirements.

We demonstrate dynamic EPA management by applying a complex filter to a standard video sequence.

2D SEPARABLE COMPLEX FILTER IMPLEMENTATION AND PLB PERIPHERAL

In the context of an embedded system, a 2D separable complex filter is implemented by cyclically swapping the row filter (1D) with the column filter (1D) via Dynamic Partial Reconfiguration.

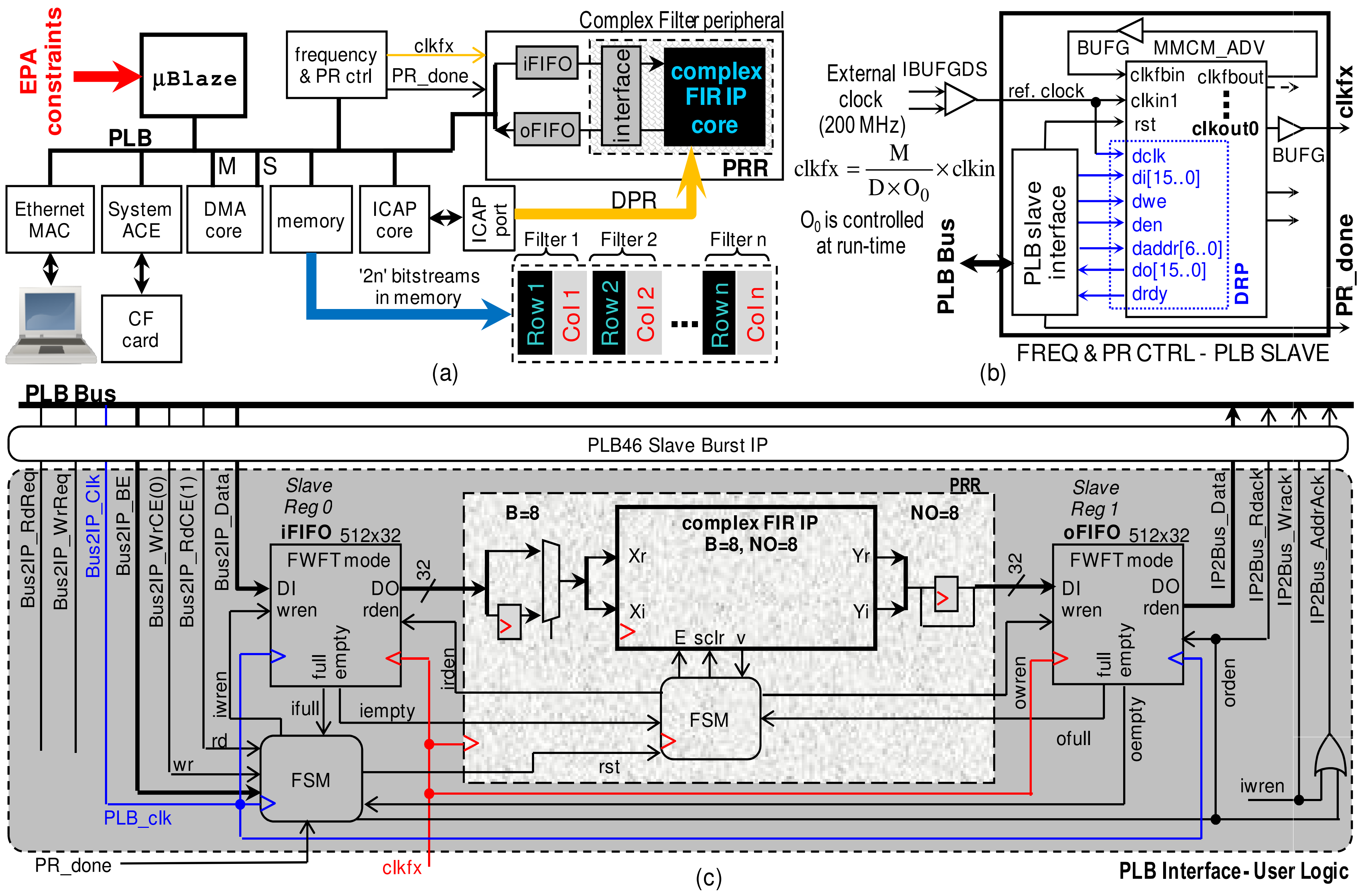


1D complex FIR Filter IP

The 1D complex FIR filter IP processes complex input data and has complex coefficients (VHDL IP core available at *www.ivpcl.org*)

Embedded System: The figure below shows an embedded system (implemented in the ML605 Board) that allows for Dynamic Partial Reconfiguration and Dynamic Frequency Control. This embedded system implements the 2D separable complex FIR filter. The 1D complex FIR filter IP is a PLB peripheral.

Dynamic Frequency Control: The Dynamic Reconfiguration Port (DRP) of the Multi-Mode Clock Manager (MMCM) inside the Virtex-6 FPGA can adjust the frequency at run-time via the parameter O_0. The complex filter is clocked at the adjustable frequency clkfx while the rest is clocked at PLB_clk (100 MHz).



OPTIMIZATION FRAMEWORK FOR 2D COMPLEX FILTERS:

The optimization framework consists of 3 steps:

1) Generate the Energy-Performance-Accuracy space of 2D complex filter realizations, by varing hardware parameters and frequency of operation.

2) *Multi-objective Pareto Optimization of the EPA space*: The EPA space is represented by a set of hardware realizations along with their EPA values. We find the optimal realizations in the Pareto (multi-objective) sense.

3) *Dynamic management based on real-time EPA constraints*: Once the Pareto front has been extracted, we can cast optimization problems based on PPA constraints. Example:

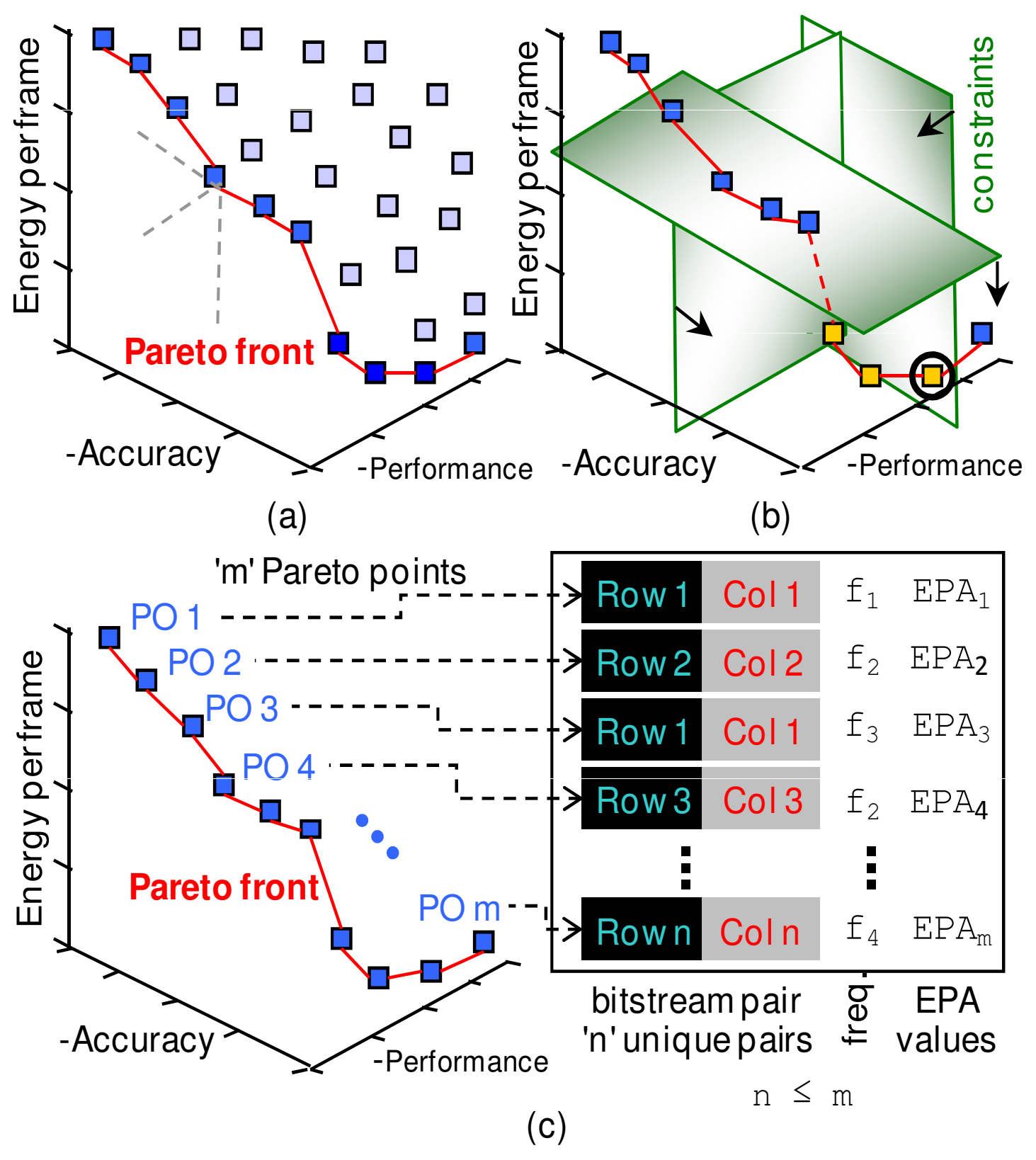
$$\min_{Ri}\ Energy(Ri) \qquad subject\ to: \begin{array}{l} Accuracy(Ri) \geq 50dB \\ Performance(Ri) \geq 30\,fps \end{array}$$

Feasible set: golden points.

Circled point: realization from the feasible set that minimizes energy consumption.

Pareto optimal point: Hardware realization that becomes active in the FPGA via DPR and/or Dynamic Frequency Control. It is represented by:

<bitstreams, freq. of operation>



EXPERIMENTAL SETUP

A complex image is processed through a Gabor separable filter (complex coeffiicients). The table shows: parameter and frequency combinations for the generation of the EPA space. N (# of coefficients), NH (coefficient bit-width), L (LUT size), OB (output bit-width). Ideal filter: 31x31 double precision coefficients. Test image: analytical lena (8-bit, CIF resolution)

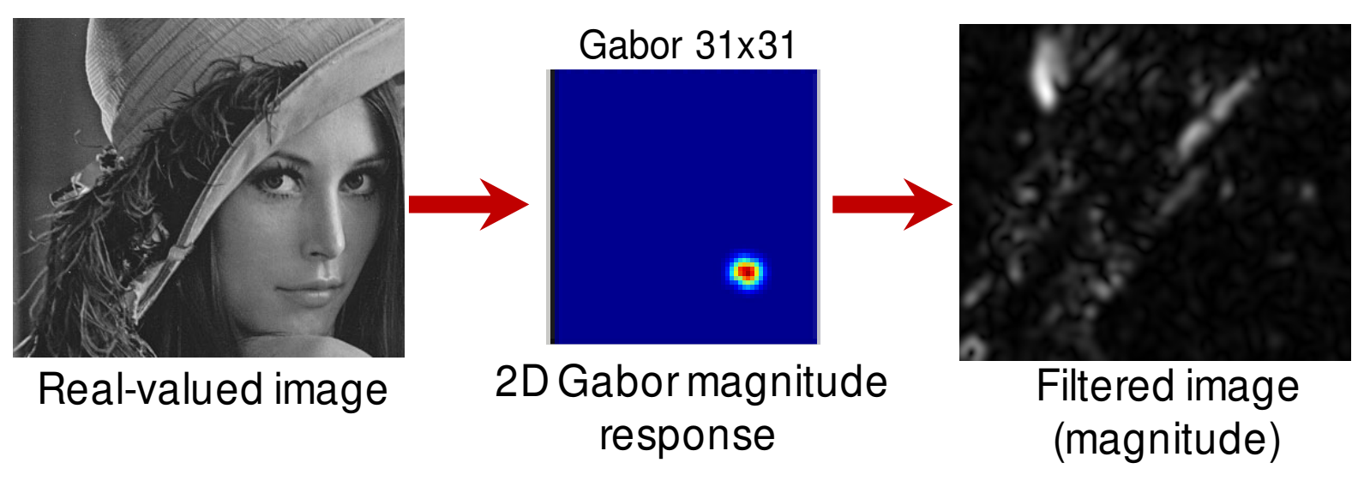


Table 1. Parameters combinations for the set of 2D complex filters. We fix the LUT input size (*L*) for a given *N*.

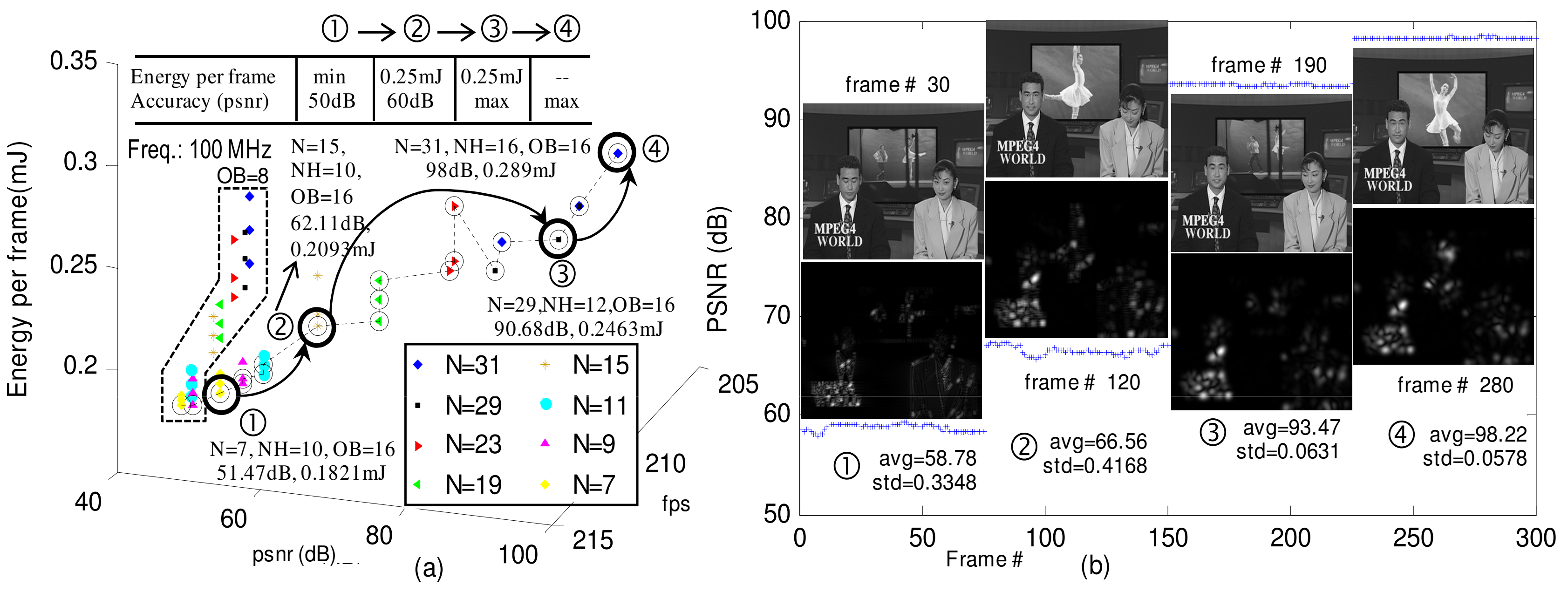
N (L)	7 (4)	9 (5)	11 (6)	15 (4)	19 (5)	23 (4)	29 (5)	31 (4)
NH	10		12			16		
OB	8				16			
freq	33.33	50		40	66.66		100	

RESULTS

Multiobjective optimization of the EPA space: The Pareto front lied entirely at the 100 MHz frequency. Thus, we carried out optimization for the EPA space at 100 MHz.

There are 20 Pareto-optimal points, that requires 20 MB of memory (40 bitstreams).

Dynamic EPA Management: Time-varying constraints applied to a video sequence. The circled points meet the constraints.



① → ② → ③ → ④

Energy per frame Accuracy (psnr)	min 50dB	0.25mJ 60dB	0.25mJ max	-- max

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