Embedded real-time system for motion and deformation measurement

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Introduction

▶ Digital image correlation (DIC) is a popular and efficient technique for motion and deformation measurements as it provides sub-pixel accuracy. But it represents a significant drawback, extremely huge computational (iterative algorithm, ...).

▶ The current solution consists on off-line processing

Figure 1: Current solution

Objectives

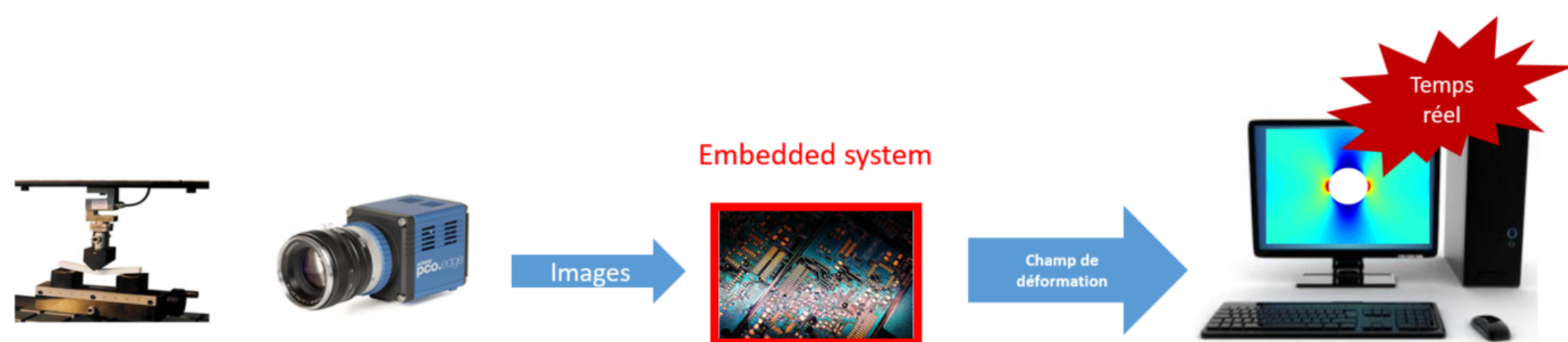▶ Field-Programmable Gate Array (FPGA) for real-time: parallelism, pipeline

Figure 2: smart camera

1. Real-time
2. Achieve high-accuracy (10^{-3})
3. Optimal architecture (Logic, DSP, memory, area and operating frequency)

DIC principle

▶ Track each image pixel by comparing gray level values of the images taken before and after deformation.

▶ Many pixels in the deformed image may have the same gray level value, hence neighboring pixels are used.
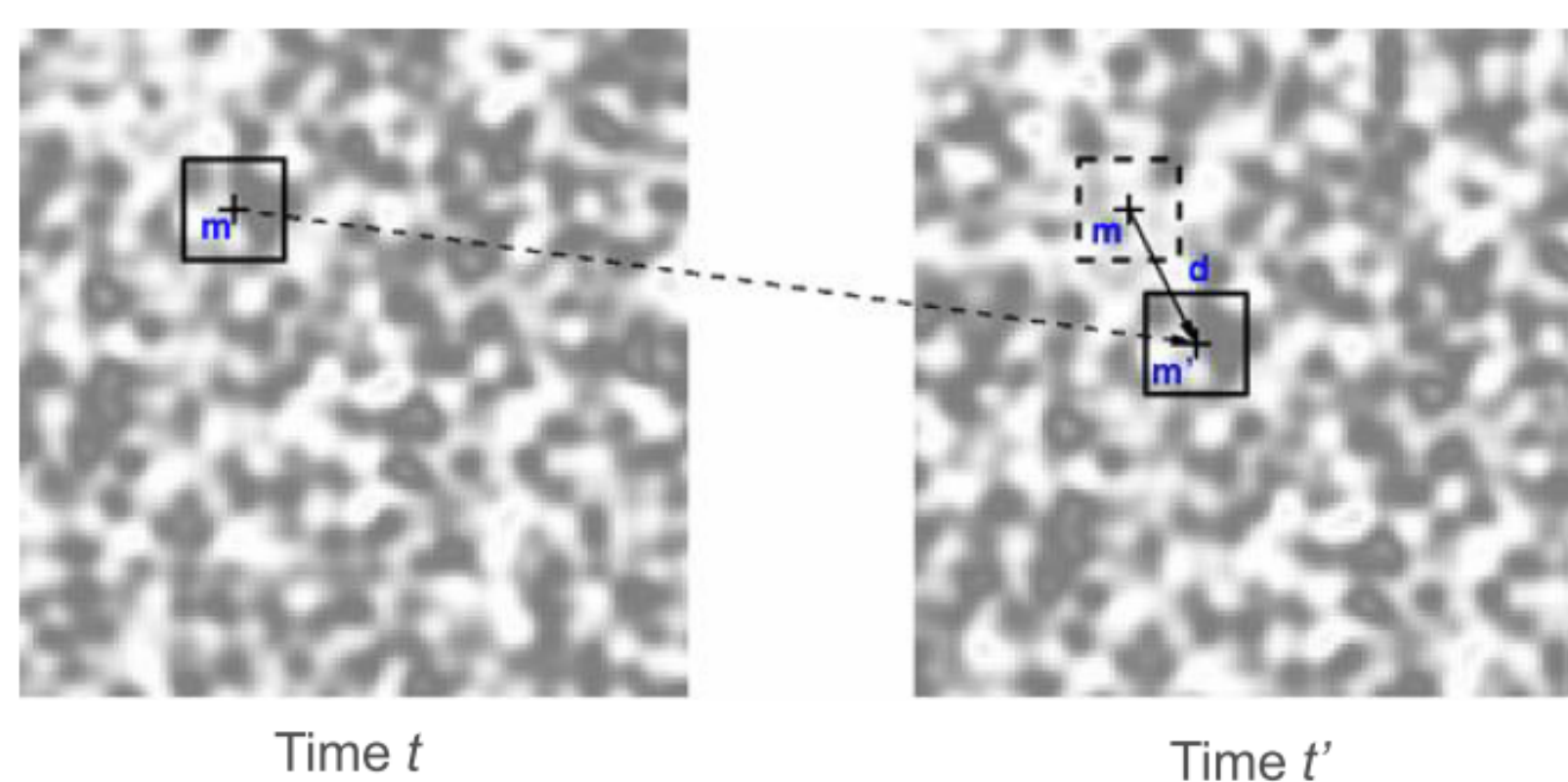

Figure 3: Subset Tracking

▶ DIC is based on minimizing the gray value difference between a reference subset and deformed subset [1].

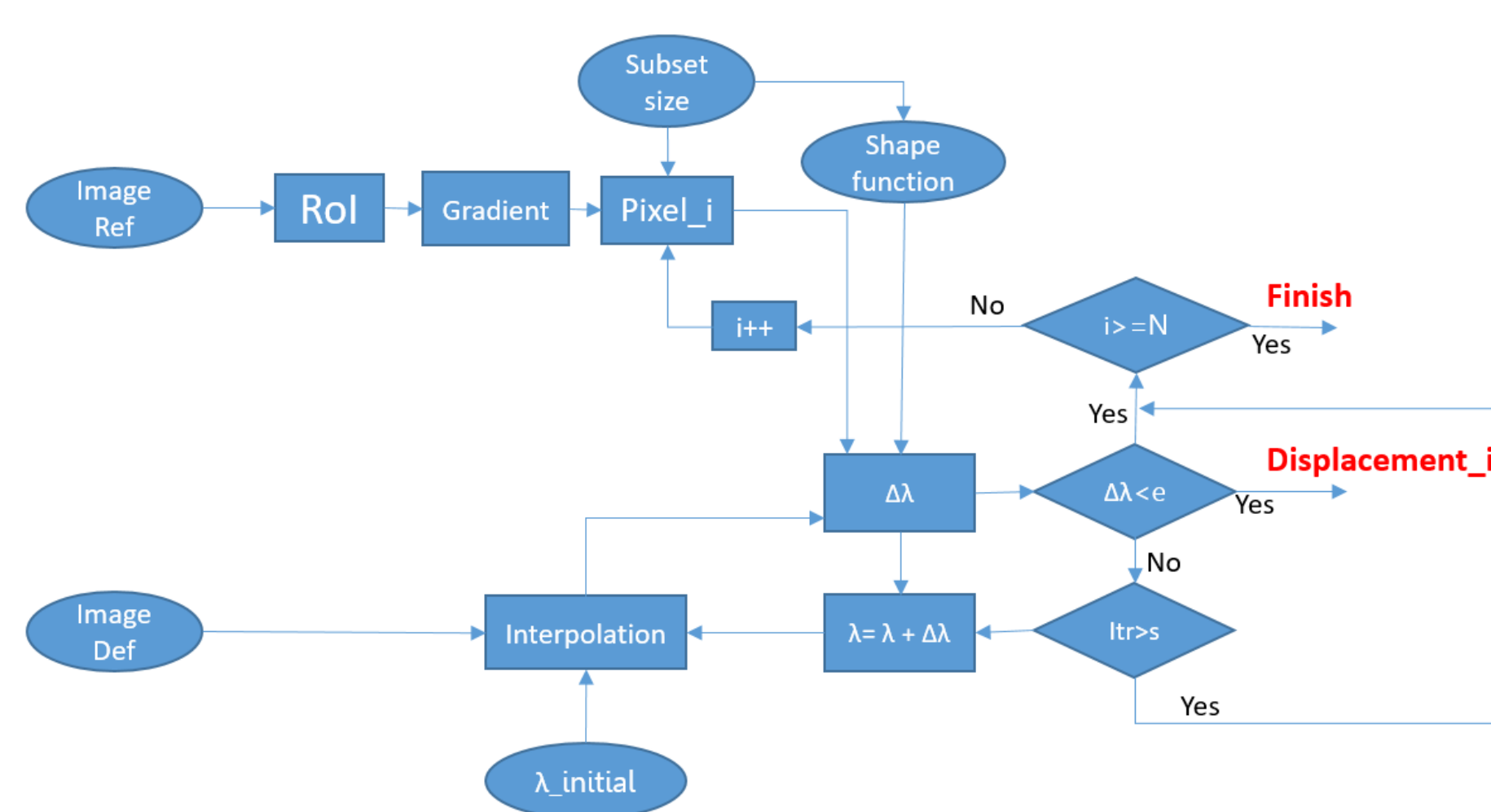$$U(X_0) = argmin \sum_{RoI} [f(X_0) - g(X_0 + U(X_0))]^2 dX_0 \qquad (1)$$

Algorithm

Figure 4: DIC algorithm

Interpolation

Method	Bi-linear	Bi-cubic	B-spline
Complexity	Low	Complex	Difficult to implement
Accuracy	Low	High	Excellent

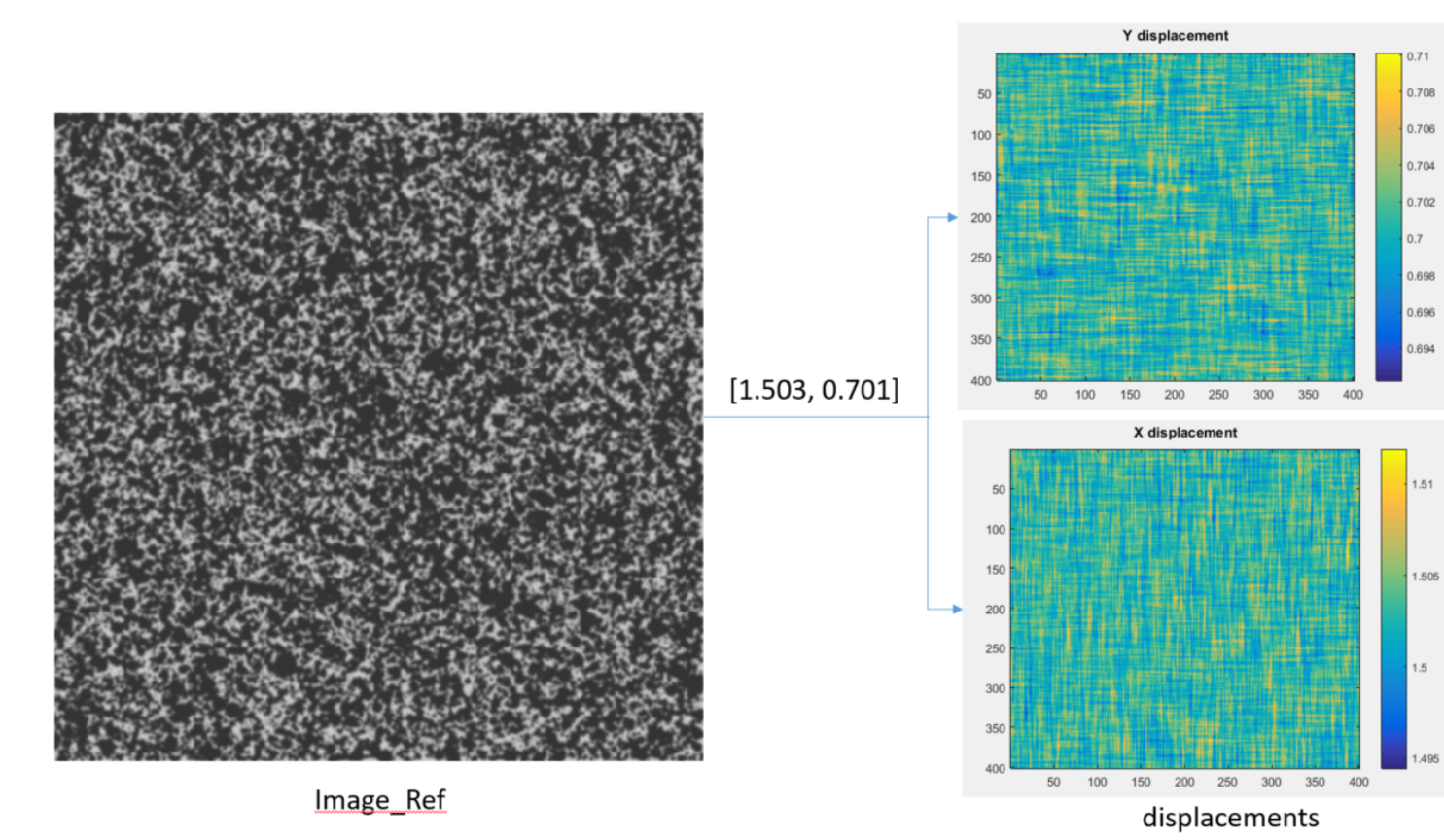Table 1: Interpolation methods [2]

Results (Matlab)

Figure 5: Translation of [1.503,0.701]

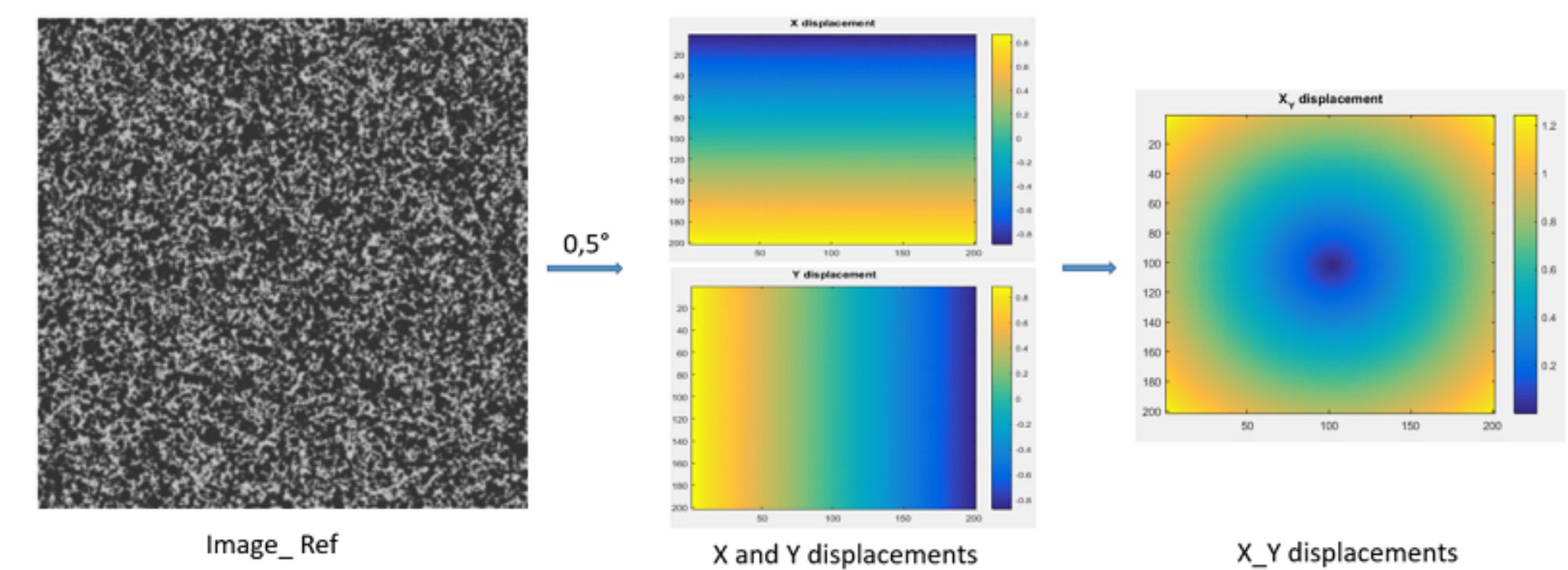

Figure 6: Rotation of 0.5°

Implementaion of Bi-cubic interpolation

▶ Hardware architecture
  ▷ Mathematic reformulation
  ▷ Avoiding redundant computations
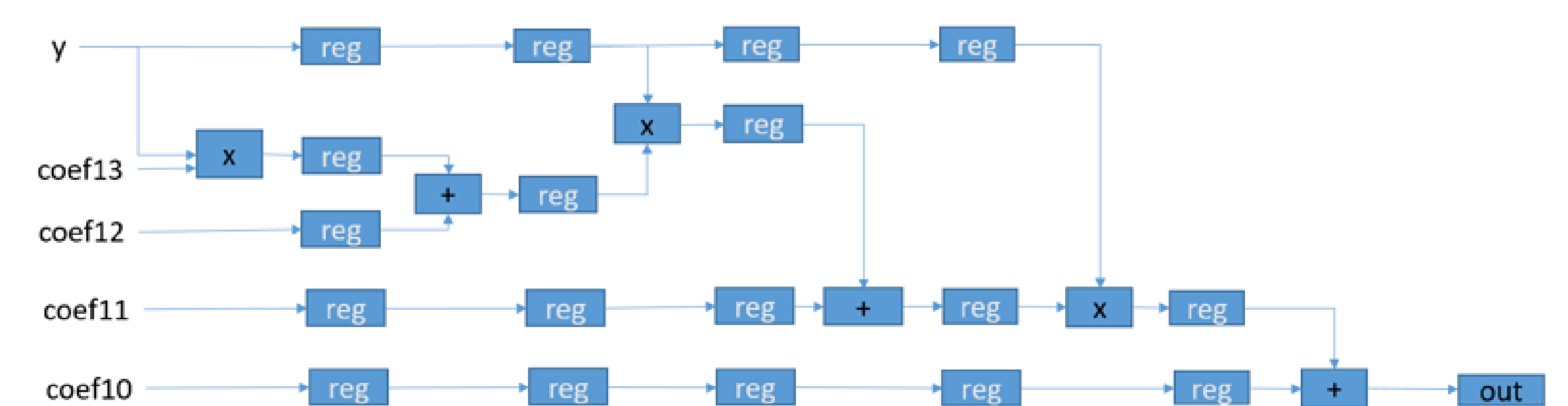▶ Coefficients block
▶ 5 bi-cubic sub-block

Figure 7: Bi-cubic sub-block

▶ The algorithm is coded in VHDL and implemented into FPGA Cyclone V

Image size	Frequency max	DSP(18x18)	Logic (ALMs)	Memory (bits)
1024x1024	204 MHz	15 (17%)	1786 (6%)	30657 ($< 1\%$)

Table 2: Resources utilization report

Conclusion and perspectives

▶ Bi-cubic interpolation is selected because it represents the best trade-off between complexity and accuracy. Our proposed architecture improves the operating frequency [3] and it is well suited for practical real-time applications such as DIC.

▶ As a perspective, the implementation of DIC based on bi-cubic interpolation is envisaged.

References

[1] Michael A. Sutton, Jean-Jos Orteu and Hubert W. Schreier. "Image Correlation for Shape, Motion and Deformation Measurements". Springer, 2009

[2] Han, D. "Comparison of Commonly Used Image Interpolation Methods". 2nd International Conference on Computer Science and Electronics Engineering (ICCSEE 2013), (Iccsee), 15561559.

[3] G.Mahale, H.Mahale, R.B.Parimi, S.K.Nandy, S.Bhattacharya. "Hardware Architecture of Bi-Cubic Convolution Interpolation for Real-time Image Scaling". International Conference on Field-Programmable Technology (FPT) 2014 .

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