Novel 3x3 image filters implemented in hardware

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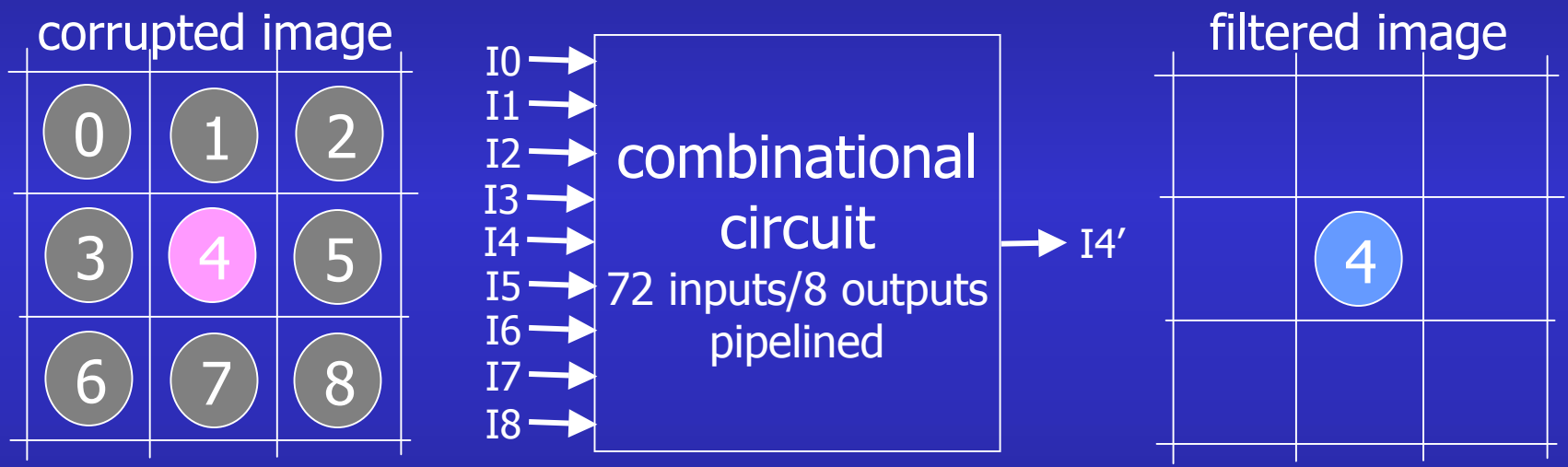
Image operators as digital circuits

kernel 3x3, gray-scale (8b/pixel) images 256 x 256 pixels



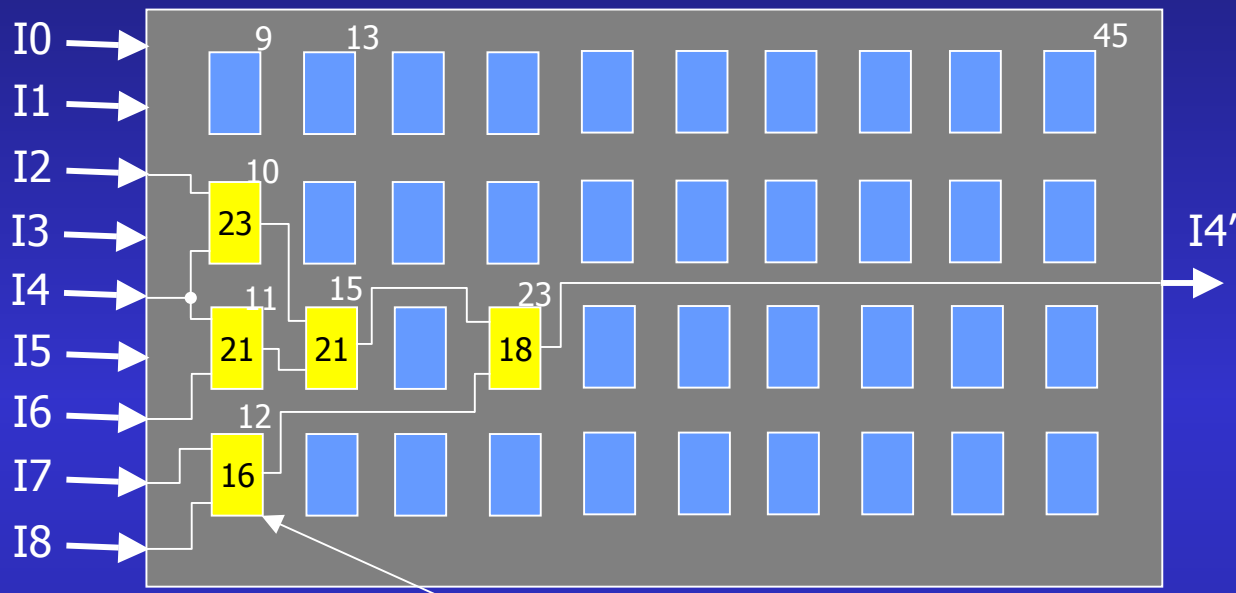
Conventional solutions

Problems:

Gaussian noise, Uniform noise, Salt&Pepper noise, Edge detectors

#equivalent gates - implementation cost in FPGA XC4028XLA

Model of the reconfigurable circuit: Cartesian GP at functional level



Definition of the RC:
#inputs: 9 x 8bits
#outputs: 1 x 8bits
Topology: 10 x 4
L-back: 2
A set of functions:
and, or, xor, not, shift, min, max, (a+b)/2, …

Chromosome:

xxx|2, 4, 23|4, 6, 21|7, 8, 16|xxx|xxx|10, 11, 21|xxx|…….|23

A very simple evolutionary algorithm:
Mutation only, 16 individuals in population, deterministic selection

Fitness function

corrupted image (Gaussian noise)

N x N pixels, N = 256

chromosome

Digital circuit

filtered image

original image

Comparator

fitness

$$fitness = 255.(N-2)^2 - \sum_{i=1}^{N-2}\sum_{j=1}^{N-2} |\, original(i,j) - filtered(i,j) \,|$$

Mean Difference Per Pixel: $$mdpp = \frac{DIFF}{(N-2)^2}$$

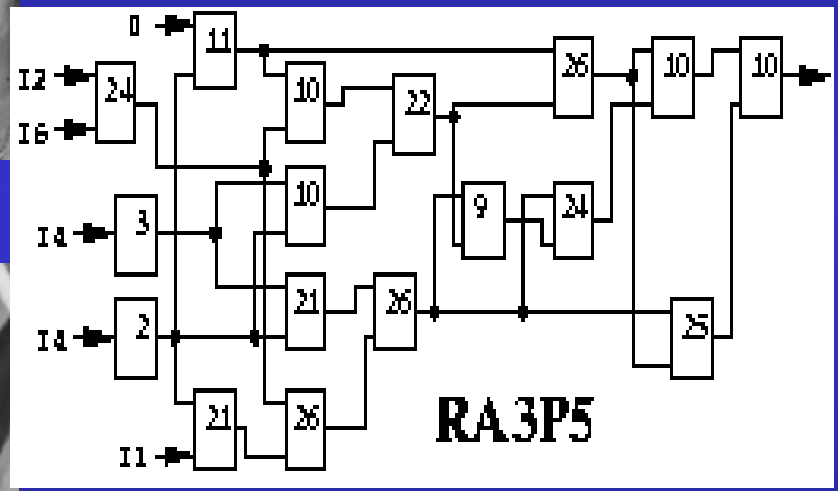
Results: Salt&Pepper noise

salt&pepper 5%

RA3P5 (1702)

RA3P5 (1702)

median (4740)



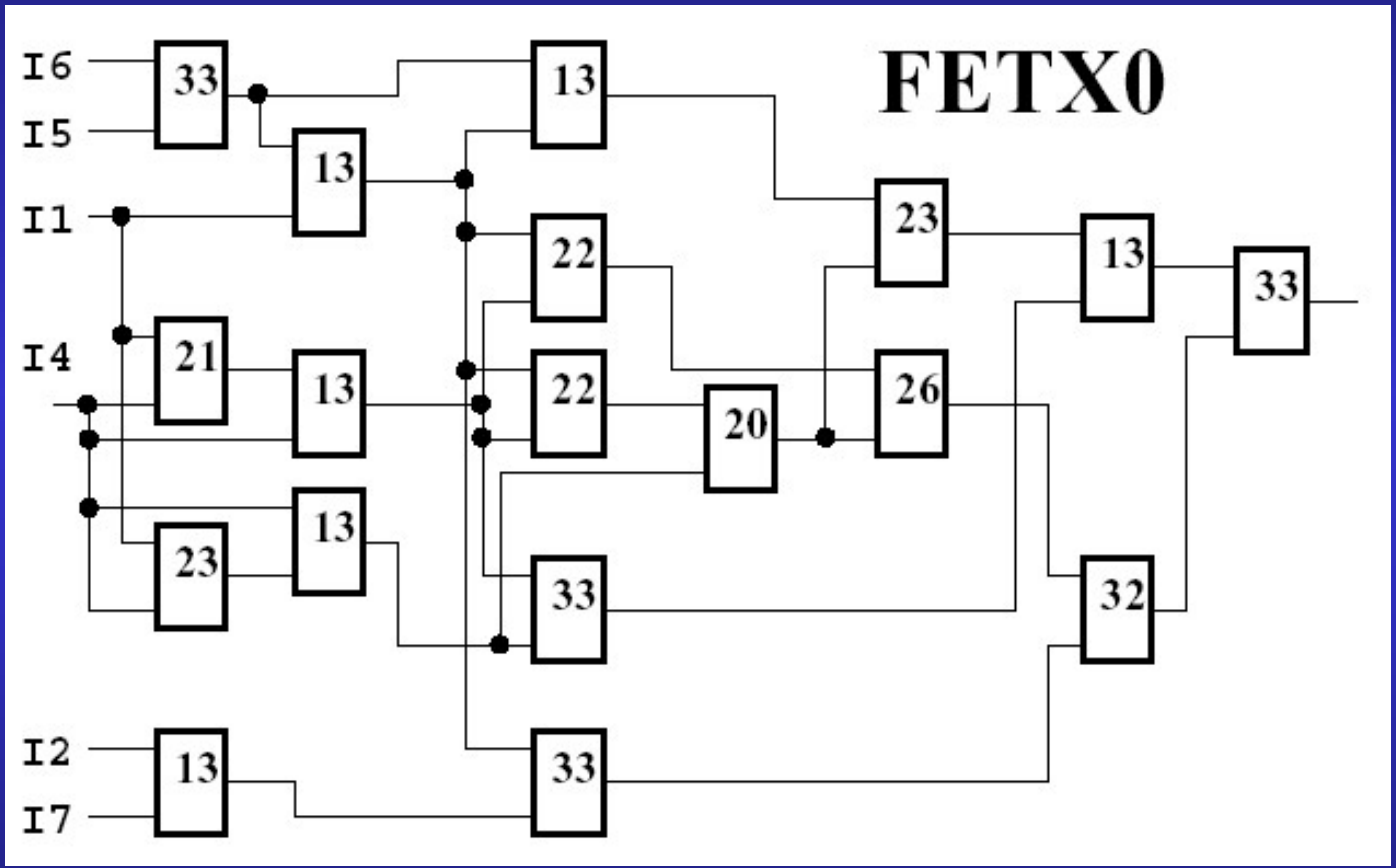
Salt&Pepper (cont.)

RA3P5 (1702)
mdpp=0.656

median (4740)
mdpp=2.954

FETX0 (2075)
mdpp=0.379

The evolved filter FETX0

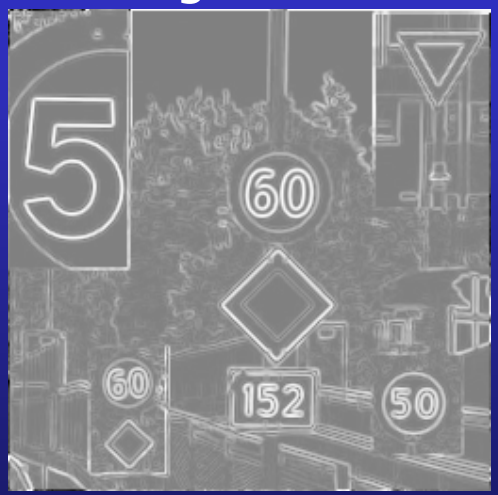


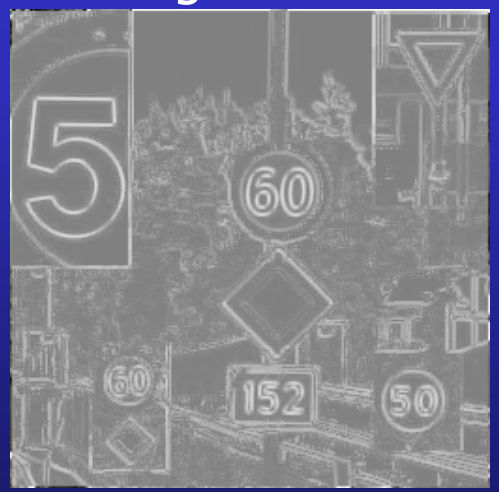
Results: Edge detectors

Sobel operator
1988 gates

FS3
1350 gates

FS7
2079 gates





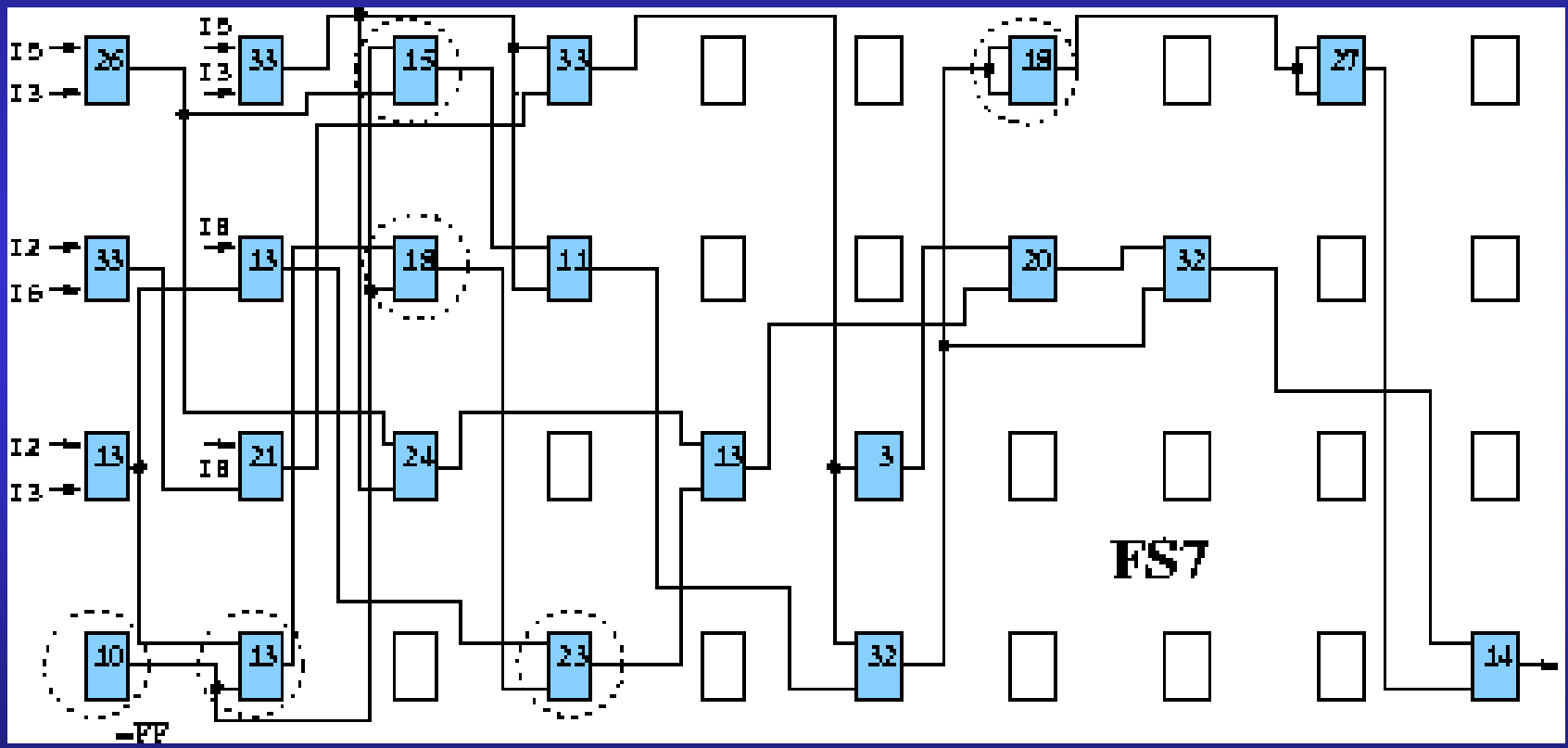
Edge detectors (cont.)

FS7 (2079)
mdpp=1.536

Sobel (1988)

FET42 (3871)
mdpp=1.203

The FS7 operator



Comments

- Evolved operators are human-competitive:
  - better than conventional ones in terms of quality (mdpp),
  - sometimes better in implementation costs
- Time of evolution depends on the required quality
  - a few hours on a common PC
  - a few minutes-seconds in FPGA (our estimate, under construction now)

I do believe that:

- A – These filters qualify today as a patentable new invention.
- D - The result is publishable in its own right as a new scientific result, independent of the fact that the result was mechanically created - mainly because of suitable hardware implementation, which could be interesting for real-world applications (embedded systems, etc.).
- F - The result is equal to or better than a result that was considered as an achievement in its field at the time it was first discovered.