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

corrupted image

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combined circuit

72 inputs/8 outputs pipelined

filtered image

4

I0 -> I1 -> I2 -> I3 -> I4 -> I5 -> I6 -> I7 -> I8

I4'
Conventional solutions

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

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<tr>
<th>conventional operators</th>
<th>FME</th>
<th>FA1</th>
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<th>Sobel operator</th>
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#equivalent gates - implementation cost in FPGA XC4028XLA

4740

1390

1371

1397

1988
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

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

Mean Difference Per Pixel:

\[
mdpp = \frac{\text{DIFF}}{(N - 2)^2}
\]
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.