

Application to the competition:

HUMAN-COMPETITIVE RESULTS IN GENETIC AND EVOLUTIONARY COMPUTATION

GECCO, June 27, 2004, Seattle, WA

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Description of the human-competitive result:

Novel image filters implemented in hardware

Published in the book:

Evolvable Components: From Theory to Hardware Implementations (Chapter 7).
Natural Computing Series (editor: G. Rosenberg), Springer-Verlag, Berlin 2004.
The book is dated: August 2003

Abstract (Chapter 7 of the book Evolvable Components)

Functional-level Cartesian genetic programming was applied to design hardware implementations of low-level, 3x3 kernel image filters (8 bits/pixel). These filters produce images of comparable or better quality than conventional, human-designed, solutions, such as convolution or median filters. Their implementation cost (the number of equivalent gates) is similar or better than in the case of human-designed solutions. In particular, the following filters were evolved: "salt and pepper" noise filters, Gaussian noise filters, uniform random noise filters, and edge detectors.

PDF file: not available because of copyright rules. The book will be available during the competition. See **Note** below.

A statement specifically identifying one or more of the eight criteria and stating why the result satisfies that criteria:

Conventional, human-designed, hardware implementations of 3x3 image filters are based on the implementation of the median circuit (i.e. on compare-swap elements) or convolution circuit (i.e. "add and shift" operations). These filters have been known and routinely utilized in image processing for a long time. If a specialized filter is required to remove a new type of noise, a designer has to experimentally determine the values of many coefficients, which is very time consuming. These values can be designed by means of a genetic algorithm (which is NOT my contribution to this competition). Typically, a structure of the filter is not usually modified.

In case of the proposed filters, their complete structure was determined by means of Cartesian genetic programming. The evolved filters are pipelined and composed of simple elements (having two 8bit inputs and a single 8bit output). These elements perform simple operations, such as logical functions, addition, average, minimum or maximum. The main feature is that the outputs of

elements are restricted to 8 bits only allowing their easy interconnection, which is suitable for hardware implementation. A human designer has not practically any chance to create a suitable operator using these elements manually, because their functions are non-linear and difficult to apply.

The proposed filters were evolved using 256x256 Lena image in the fitness function and tested on various other images. The evolutionary design takes a few hours on a common PC (depending on the required quality). A complete hardware implementation of the evolvable system is under construction now. The estimated time of evolution is a few minutes or seconds (depending on the required quality).

We evolved very good filters in order to suppress: "salt and pepper" noise, (e.g. RA3P5 and FETX0 filters in the book *Evolvable components*), Gaussian noise (F24, F23), uniform random noise filters (F21), and edge detectors (FS3, FS7). These filters are better than conventional ones in case that either (1) the visual quality or (2) implementation cost or (3) the visual quality as well as implementation cost are measured.

The main advantages of the proposed filters are:

High quality of generated images

Non-expensive hardware implementation

Tunable ratio: quality vs. implementation cost

No designer is needed during the design process

I believe that these filters satisfy the following criteria:

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.

Note:

The results nominated for this competition and published in Chapter 7 of the book *Evolvable components* were also summarized in the following paper. This summary of results was utilized for comparison with the results of (easily testable) filters presented in the paper. The paper is attached in order to help the committee in case that my book is not available.

Lukas Sekanina and Richard Ruzicka: Easily Testable Image Operators: The Class of Circuits Where Evolution Beats Engineers. In: Proc. of the 2003 NASA/DoD Conference on Evolvable Hardware, Chicago, USA, IEEE Computer Society Press, Los Alamitos, 2003, p. 135–144

Abstract:

The paper deals with a class of image filters in which the evolutionary approach consistently produces excellent and innovative results. Furthermore, a method is proposed that leads to the automatic design of easily testable circuits. In particular we evolved "salt and pepper" noise filters, random shot noise filters, Gaussian noise filters, uniform random noise filters, and edge detectors.

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Brno, June 20, 2004