SOFTWARE IMPLEMENTATION AND HARDWARE ACCELERATION OF RETINAL VESSEL SEGMENTATION

EMBC'17 JeJu, Korea

L. Cavinato, I. Fidone, M. Bacis, E. Del Sozzo, G. C. Durelli, M. D. Santambrogio
{lara.cavinato, irene.fidone, marco.bacis} @mail.polimi.it,
{emanuele.delsozzo, gianlucacarlo.durelli, marco.santambrogio}@polimi.it
Politecnico di Milano
Dipartimento di Elettronica, Informazione e Bioingegneria

Rationale & Contribution

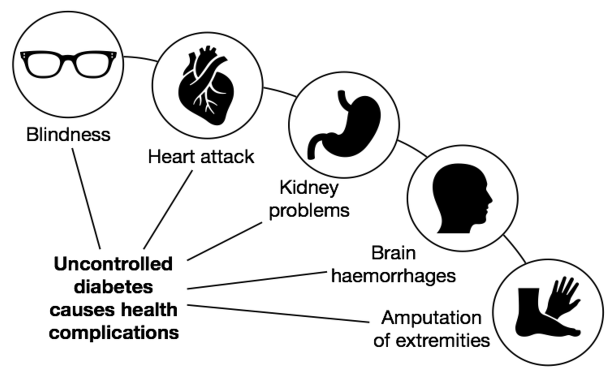
Screening tests are an effective tool for the diagnosis and prevention of several diseases. Unfortunately, in order to have an **early diagnosis**, the huge number of collected samples has to be processed **faster** than before. In particular this issue concerns image processing procedures, as they have a **high computational complexity**, which is not satisfied by modern software architectures.

Solution: Field Programmable Gate Arrays (**FPGAs**) can be used to accelerate partially or entirely the computation.

Case study: Retinal vessels Segmentation for **Diabetic Retinopathy screening tests**.

Context Definition

Diabetic Retinopathy (DR) is a complication of diabetes, it is caused by blood metabolic decompensation which brings to irregular micro-vascularization.

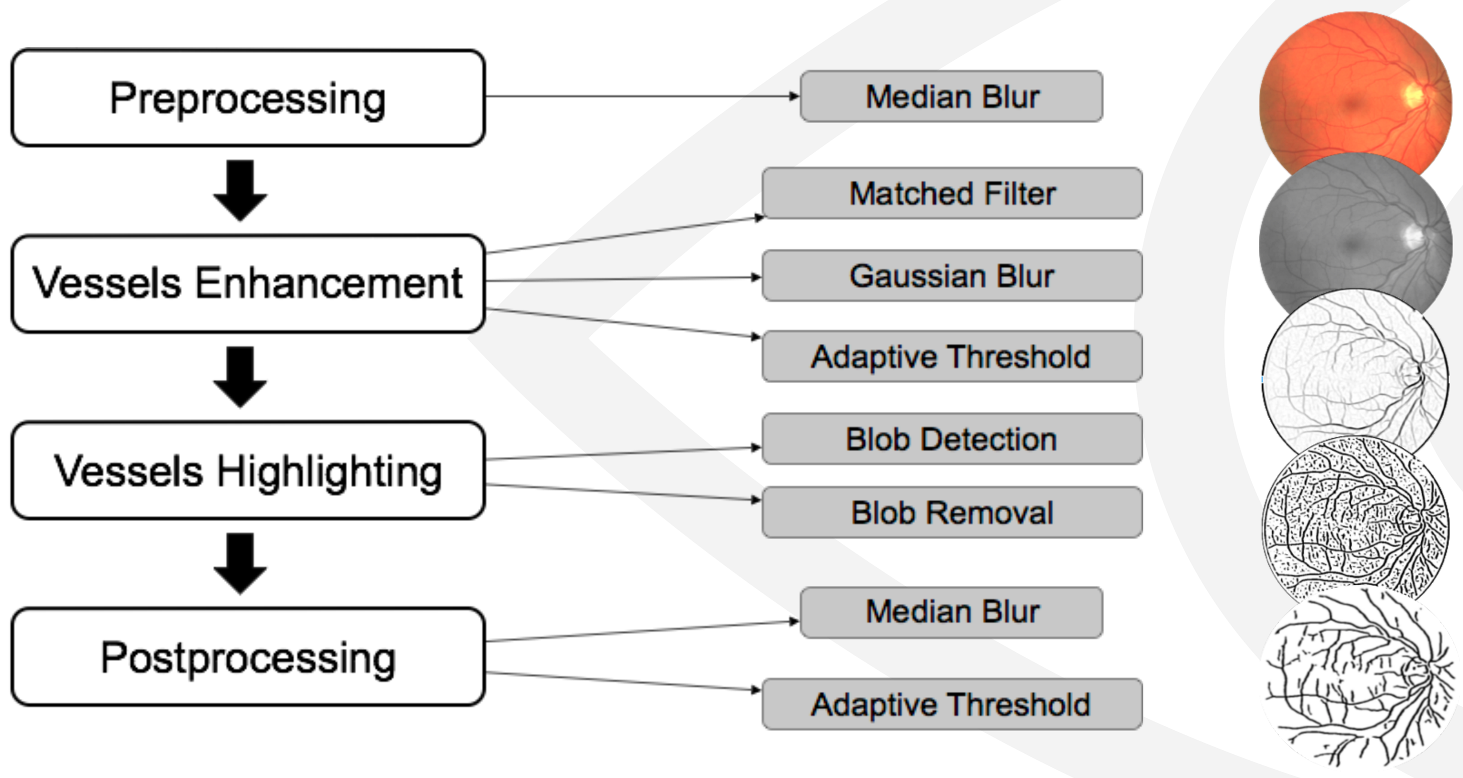


Segmentation is a technique that allows the partitioning of a digital image in two or more areas. In digital image processing, it enables the region of interest detection.

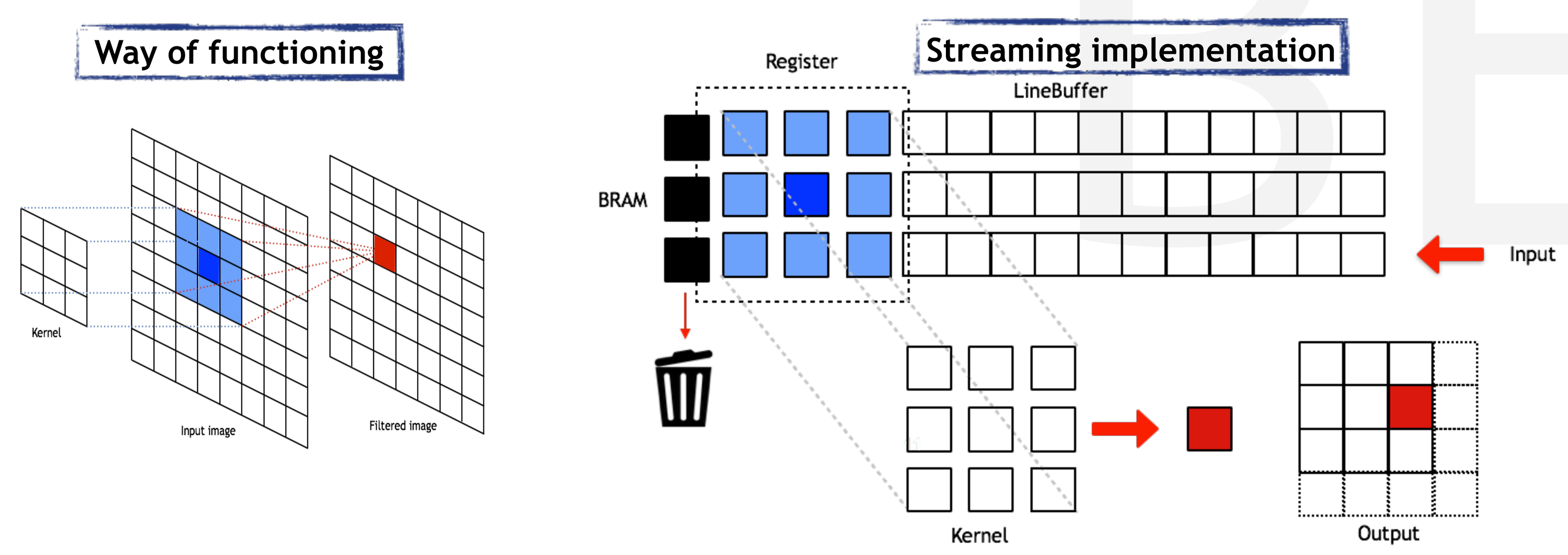
DRIVE [1] and **STARE** [2] Databases were used to evaluate our work.

Proposed Methodology

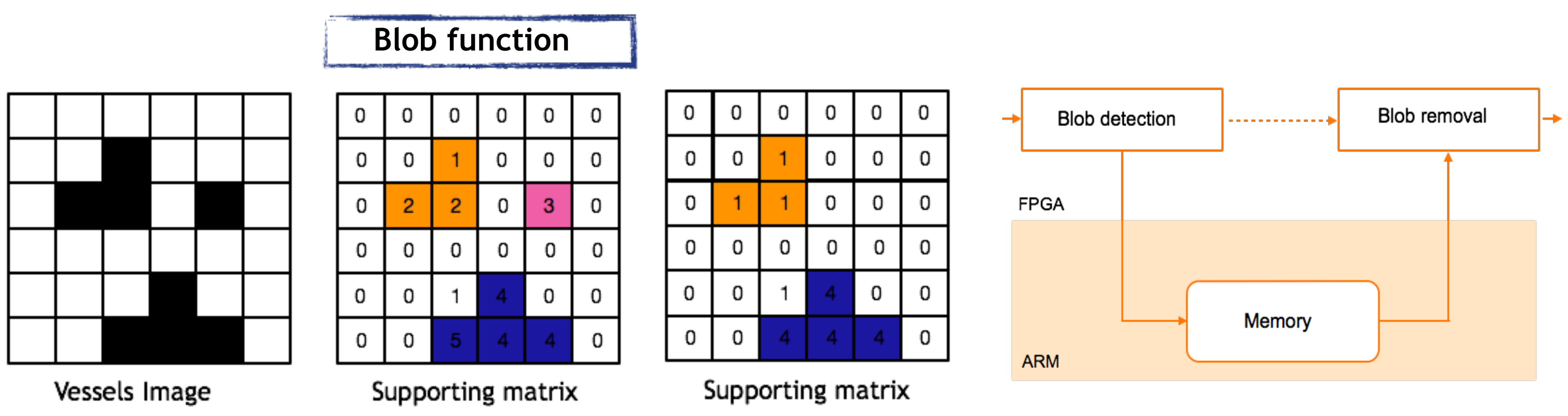
Algorithm: the proposed methodology consists in a pipeline of filters that process an input retinal image in order to detect the blood vessels. Each function corresponds to a hardware core.



Convolution is the main operator which join all the filters implementation, except for blob vessels structure highlighting step. It exploits:
- FPGA **BRAM** for storing image rows in a steaming architecture;
- FPGA **registers** to store kernels;
- **Pipelinig** and **unroll** pragmas to achieve maximum throughput.

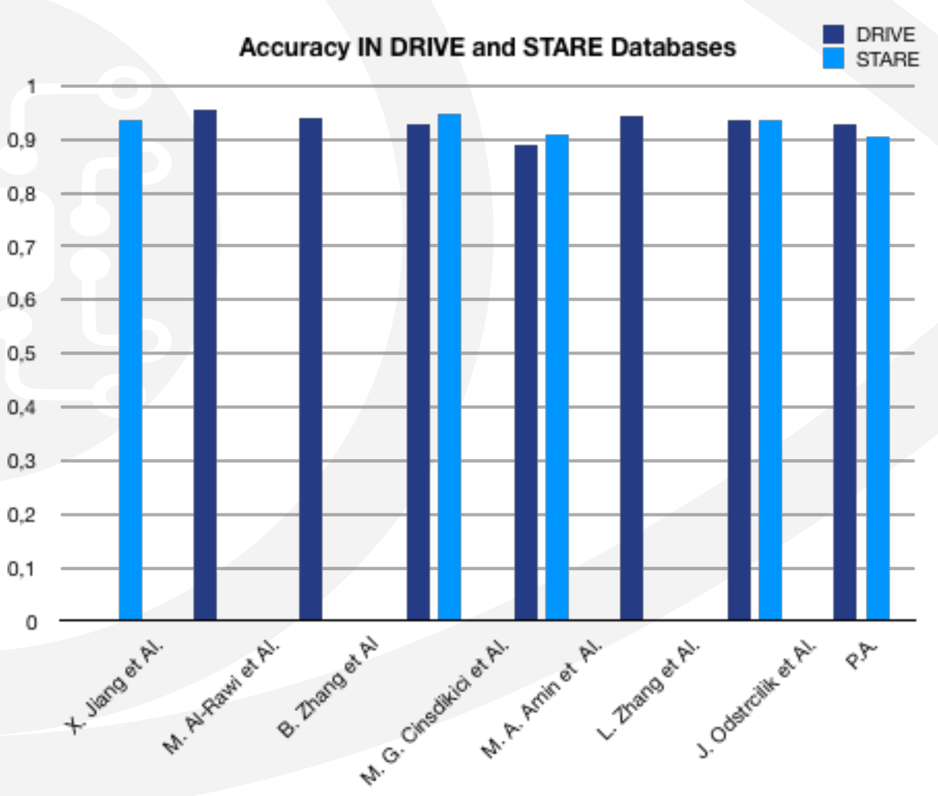


Blob detection and **blob removal** algorithms have been implemented differently. Since they are not linear filters, convolution can not been exploit. They basically consist on a **threshold** to single out vessels blob from noise. Here comes the need of use ARM memory to store the entire image.



Evaluation and Results

The Key Performance Indicators (**KPIs**): Accuracy and the latency of the implementation. The **accuracy** is the ratio between the correctly classified pixels count and the total number of pixels in the image. Then **latency** represents the average time to process a picture.



Work	Execution time DRIVE	STARE
X. Jiang et Al. [3]	-	19 s
M. Al-Rawi et Al. [4]	11 s	-
B. Zhang et Al. [5]	-	10 s
M. G. Cinsdikici et Al. [6]	35 s	-
M. A. Amin et Al. [7]	2 s	-
J. Odstrcilik et Al. [9]	3.22 s	4.07 s
P.A.	0.068 s	0.073 s

Implementation	Software	Hardware
Device	Intel Core i7	Zedboard
Execution time	0.06806 s	0.01041 s
Power consumption	26.929 Watt	4.749 Watt

The **software implementation** has been written in C++, using OpenCV [12] libraries. The test was run on a Intel Core i7-6700 CPU [13]. The architecture for the **hardware implementation** is an Avnet Zedboard [14] powered by a Xilinx Zynq-7000 All Programmable System on Chip.

Work	A. Nieto et Al. [10]	D. Koukounis et Al. [11]	P.A.
Device	Spartan 3	Spartan 6	Zedboard
Accuracy	0.9100	0.9007	0.9285
Execution time	1.4 s	0.03185 s	0.01041 s
Frequency	53 MHz	100 MHz	100 MHz

The possibility to have a very **low computation time**, allows to cut down on waiting times by providing a support for **real-time** diagnosis.

Future Work

Development of the implementation for the automatic detection of the diabetic retinopathy:
- Detection of the **micro-aneurisms** (non proliferative stage)
- Comparison of the vessels' structure (**neoangiogenesis**)
- Creation of an **embedded system** to perform screening tests

References

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