Technical Report – FPGA image preprocessing: high performing, versatile and revolutionarily easy

Going new ways

Demanding inspection tasks entail enormous data amounts and high processing effort. Intelligent image preprocessing migrated from the PC into the camera's FPGA (Field Programmable Gate Array) opens new approaches for increased throughput or reduced system costs. The major challenge is to make this technology controllable for end users.

Standard cameras in machine vision applications usually transfer non-compressed image data of the field of view to the PC for evaluation. Only simple tasks such as image optimization or color computation are performed in the camera itself. The image processing is done in the PC later on and these functionalities cannot be adapted to application-specific requirements by the user. Additionally, many applications pose ever-growing requirements on resolution, frame rate, quality and image processing reliability. In favor of this, image sensors, interface connectivity and high-performance PCs already enable data transmission and processing at the speed of several gigabytes per second. But their use often entails considerable implementation effort through system modification or even in-house developments. Therefore they are not always the best and most cost-effective solution. But what are the alternatives? Baumer *VisualApplets* cameras of the LX series are an innovative approach and show how easy portions of image processing can be done in the camera itself.

The repartition of image preprocessing

Alternatively to proven PC-based solutions, the intelligent approach by Baumer involves the camera's FPGA for solving demanding inspection

New LX *VisualApplets* cameras enable integrated, application-specific image preprocessing straight in the camera's FPGA for efficient, high-resolution and high-speed image processing.
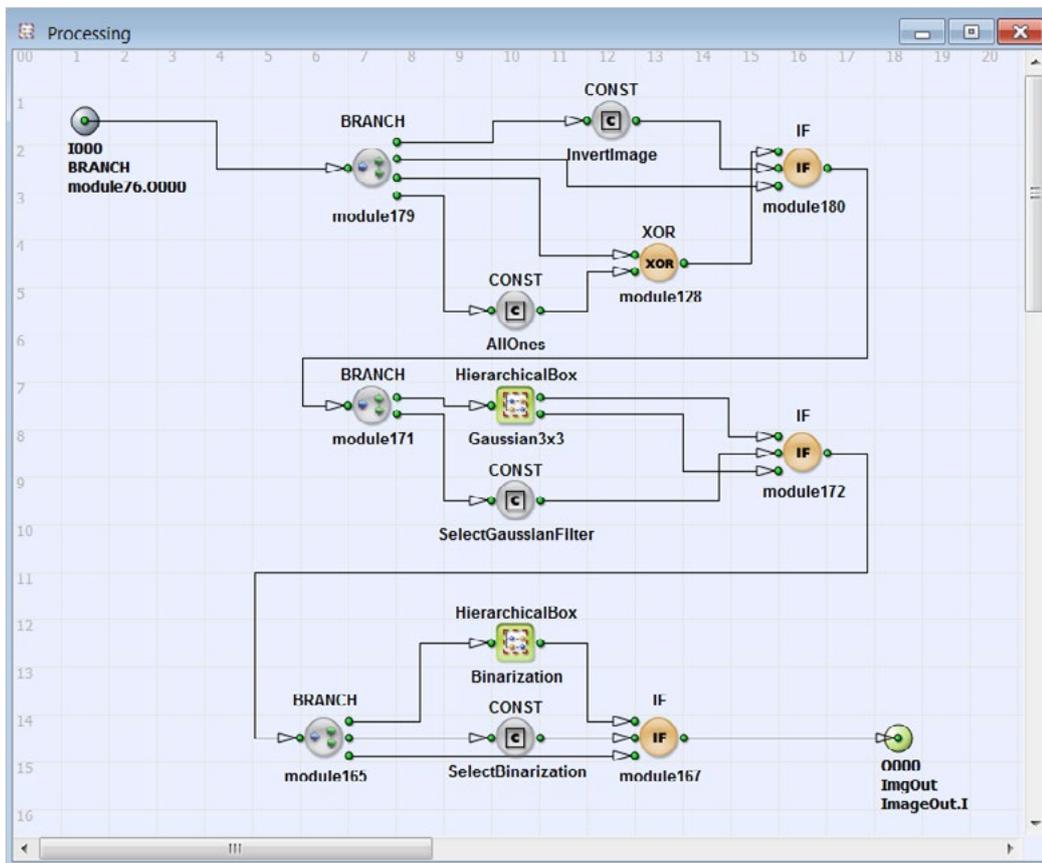
With *VisualApplets*, the graphical development environment by Silicon Software for FPGA programming, even complex algorithms can be quickly and easily defined and flexible adaptation of camera functionalities is possible.

tasks. Conventional industrial cameras in PC-based image processing systems typically use it as central processing component for sensor control and correction, for simple image processing as well as for controlling interfaces regarding data output and digital I/Os. This is possible because of its versatile programmability and high performance. Following the technological semiconductor developments, every next FPGA generation comes with enhanced capacity, performance and energy efficiency. As a consequence, the technology is ideal for demanding image processing tasks straight in the camera to meet ever-growing application requirements and to find a way round system modifications or customer-specific developments. That's where the new LX camera models with *VisualApplets* technology come into play. They are capable of application-specific image preprocessing straight in the camera's FPGA and integrate sensors with high-resolution and speed. Three models with 4, 12 or 20 megapixel resolution and standard-compliant GigE Vision® interface meet most different application requirements.

Various fields of application and just as many benefits

The integrated FPGA of the LX *VisualApplets* cameras can be quite versatile for use in image preprocessing tasks. The emphases are on improved image quality, reduced amount of data or process monitoring. In addition, complex control tasks via digital I/O interface can be implemented efficiently.

Some examples for image enhancement: Noise reduction by image averaging, HDR computing by recording several images with different exposure times or correction of non-homogeneous illumination for significantly simplified and more reliable PC image evaluation in the next step.

Thanks to the data reduction within the camera, the amount of data for transmission and evaluation is cut down and consequently allows for cost-efficient interfaces such as GigE, with high flexibility in terms of cable length in parallel. Additionally lower PC requirements and less sophisticated or limited peripheral devices will reduce overall system costs. Reduced data amount
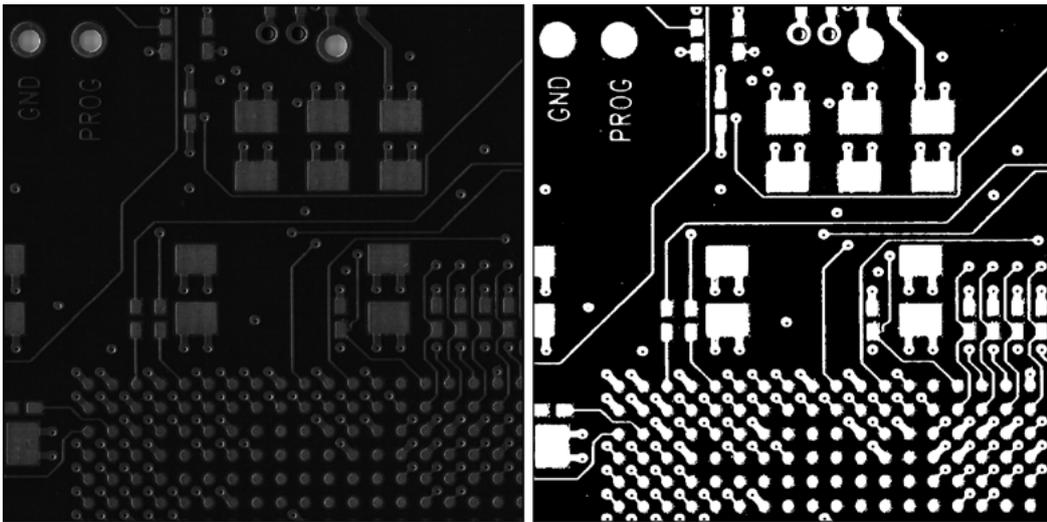
Image enhancement and data reduction are possible applications for simplified and faster image evaluation (left: original image, right after processing).

is a special benefit in 3D image processing, for example profile data generated by laser triangulation or when acquiring specific marker details. Additionally, when detecting non-aligned parts on a large conveyor belt, the camera can locate and transfer only the relevant object to the PC. Another example is pre-selection in an image sequence from which only the image with the highest contrast is transmitted. For some evaluation tasks like code reading, black/white information is sufficient and binary images considerably reduce the amount of data in further processing.

Process control tasks become a major focus, especially when very fast processes must be monitored and controlled as required in high-dynamic laser welding. The FPGA's deterministic behavior and high computing capacity allows improving the response time. Tracking of the eye position in ophthalmology is similarly demanding in terms of real-time requirements.

Via the FPGA, sensor evaluation or actuator triggering can be done very precisely. This is a special benefit in Track & Trace applications where objects are detected by light barriers, tracked on the conveyor belt by encoders and sorted after image evaluation. Furthermore, specialized trigger or illumination controls can be implemented flexibly with the LX *VisualApplets* cameras. Also object information on properties or position is directly transmitted to other controls, like needed in Pick & Place applications.

With *VisualApplets* easier than ever before

Complex FPGA programming is one of the main user drawbacks associated with camera-based, application-specific image preprocessing.

Conventional solutions with hardware language like VHDL are protracted and expensive; often the required know-how is not present in-house. LX *VisualApplets* cameras by Baumer follow a new approach. Based on a partnership with Silicon Software they allow implementation of the image preprocessing tasks with the graphical development environment *VisualApplets*. The cameras integrating high-capacity FPGA and memory capabilities are programmed according to application requirements by software engineers using *VisualApplets*. The functionality is based on graphical representations in the form of block diagrams while the implemented operator libraries provide every essential function in image processing. At any point of the algorithm design, the visual processing result can be simulated and displayed. Complex control mechanisms support the software engineers while creating a synthesized design with deterministic behavior. Thanks to the function variety and intuitive operation even complex tasks can be quickly and easily implemented without need for VHDL programming. Once the algorithms have been defined in *VisualApplets*, the algorithm design is compiled to a new firmware and uploaded in the camera using the update tool. The algorithm parameters are exported via the camera's XML file for standard-compliant runtime adjustment by the PC software. Several example applets enable rapid evaluation and convenient specific adjustments.

Integrated image preprocessing: added value in focus

Put simply, camera-based image preprocessing will significantly enhance application performance,

precision and robustness in image evaluation as complex algorithms run directly in the camera's FPGA. Intelligent reduction of data volume in the camera cuts down on transmission and evaluation time and will speed up the application throughput. Conventional solutions with faster interfaces such as Camera Link® do not provide the same flexibility in cable length or the significant cost reduction in system integration and design.

Standard complex FPGA programming is old news. The future is user-friendly cameras with *VisualApplets* that allow even the non-expert in FPGA programming to define the required algorithms. Now the user can solve various demanding tasks which previously required customer-specific product developments.

More information:
www.baumer.com/VisualApplets-Cameras

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