White Paper

Selection and integration of ARM®-based boards for machine vision applications.

Use of ARM®-based hardware platforms with industrial cameras under Linux®

For many machine vision applications, the use of an ARM® architecture is an alternative to using PCs. In this White Paper you will learn necessary information about the selection and integration of suitable ARM®-based hardware platforms for embedded vision systems. Selection criteria will be shown and selected boards will be examined. This White Paper will also show what software integration options exist and how these can be implemented, for example with the Baumer GAPI Software Development Kit (SDK) for ARM®-based boards.

Table of content

1 Introduction

Most applications for industrial image processing use PC-based systems. Embedded vision systems are growing in importance, however, by virtue of their continuously improving computing power, compact size and low system costs.

Embedded systems are developed for specific tasks. The CPUs used are therefore optimized differently, for power consumption, size and costs. As CPUs, ARM® processors can be used, as in many consumer products, or Digital Signal Processors (DSP) or combinations of FPGA (Field Programmable Gate Array) and ARM® processors (system-on-chip, e.g. Xilinx® Zynq®). In particular ARM® processors have become very popular in recent years thanks to their low electrical but high computing power – mainly in mobile applications such as in smartphones. Due to the vast quantities of such devices in the consumer sector, a large number of powerful ARM®-based boards are already available at reasonable prices. In this way, new application fields can be opened up, for example in the field of industrial image processing.

A typical example of an ARM®-based board is the ODROID-XU4. It offers all important interfaces in credit card format for autonomous operation and uses Linux® as its operating system.

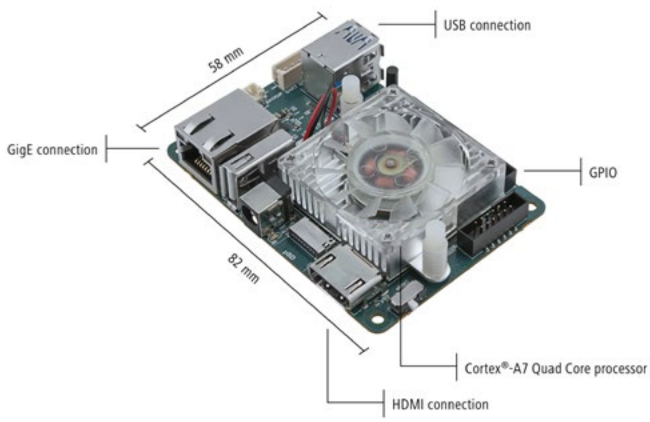

Fig. 1: ODROID-XU4

Depending on their performance, the boards currently available on the market can be used for different machine vision applications, either directly or, in the final analysis, for an advanced development in order to create a separate application-specific board. In this way, optimum long-term solutions can be implemented – an important aspect for industrial applications and their need for the long-term availability of all components.

2 Advantages of ARM® processors for embedded systems

The use of ARM® processors for embedded systems offers various advantages in contrast to Intel® processors used in conventional PCs:

- Energy efficiency: ARM® processors are characterized by particularly low energy consumption.

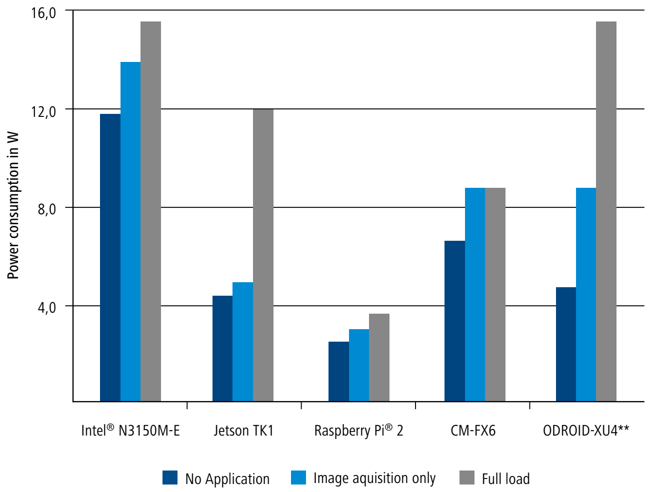

Fig. 2: Power consumption ARM® vs. Intel®
**) In this diagram, the ODROID-XU4 is the only platform to use eight cores (the others have four cores)

- Compactness: With their reduced size and lower weight, ARM®-based systems offer advantages in the integration into a higher-order system, for example in a machine. Thanks to their compact design, they can also be retrofitted more easily in existing systems. The possibility of decentralization of computing power also offers new approaches for system concepts.
- Costs: ARM® processors are very common on the market for embedded systems. Practically every smartphone or tablet computer is already equipped with one. This means that a large number of reasonably priced ARM® processors are available to create low-priced systems.
- Performance: There are numerous ARM®-based platforms by various suppliers with different designs and performance classes. Driven by innovations in the consumer sector, there will also be significant performance improvements in ARM® processors in the years to come.
- Operating systems: Linux® has now become well-established, particularly in embedded applications, where it is available for almost all evaluation platforms. Existing software solutions for image processing can be ported onto ARM®-based platforms easily and without new developments. The operating systems Android and Windows® are supported by some platforms as well.

3 Selection criteria for ARM®-based boards

Numerous ARM®-based hardware platforms are being offered on the market, and these must be evaluated according to the requirements of the specific application. Typical selection criteria for machine vision applications are:

- Processor: Which ARM® processor is suitable? How high is the CPU load for frame grabbing?
- Interfaces: Which interfaces are available, and with which bandwidth, e.g. GigE?
- Functionality: Which Linux® distribution is used? Are "jumbo frames" supported?

The following table lists boards that have been successfully tested by Baumer for machine vision applications.

ARM®-based board	Linux® distribution
NVIDIA® Jetson TK1 [2]	Linux® for Tegra® (Ubuntu® 14.04)
Raspberry Pi® 2 Model B [1]	Raspbian
CompuLab CM-FX6 (SBC-FX6) [4]	Debian®
ODROID-XU4 [3]	Ubuntu® 15.04

Table 1: Overview of tested ARM®-based platforms

The most important selection criterion for a suitable platform is the processor. Since as a rule image processing applications are very complex systems requiring high computing power, practically the only processors worth considering are those of the Cortex®-A family. These have been specially developed to solve complex tasks, and at the same time still have extremely high energy efficiency. So far, Cortex®-A processors are the only ARM® processors (as of November 2015) that can execute a full operating system. Some boards also have special graphic processors (GPUs) that are adapted exactly to image processing tasks.

The following diagram shows examples of processor workload (measured with optimized network settings) for two ARM®-based platforms for frame grabbing from a camera (without image processing). Here the GigE interface was used and a camera setting was chosen to make maximum use of the Ethernet bandwidth. In the first case, the Raspberry Pi® 2 (Model B) with only one processor of the ARM® Cortex®-A7-based architecture with four cores and a maximum clock frequency of 900 MHz was used, and the second used the powerful Jetson TK1 evaluation board by NVIDIA® with one processor with ARM® Cortex®-A15-based technology. This also has four cores, but has a maximum clock frequency of 2.3 GHz.

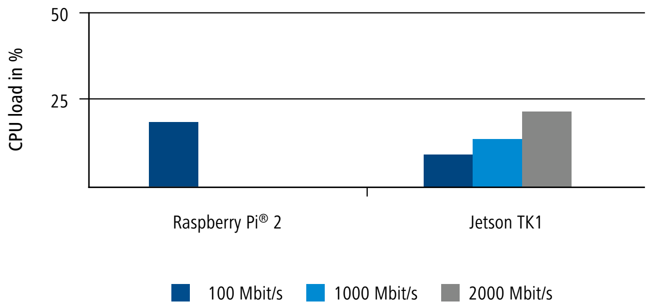

Fig 3: CPU workload for frame grabbing depending on the data rate (maximum data rates are only slightly less than the theoretical values)

The available interfaces on a board are also decisive in application selection. For machine vision applications, these are the Ethernet and the USB 3.0 port for the camera connection. In addition to sufficient USB ports, which are required for the use of input devices, the video output is also critical. It is usually necessary to connect a monitor for evaluation purposes, and the evaluation platforms usually provide HDMI connections for this. To allow integration into a system, many platforms offer other interfaces, for example Display Interface (DSI) or Display Port. A further interface is offered through GPIO pins, which allow the use of further peripheral amplifiers.

ARM®-based board	USB	Ethernet	HDMI
NVIDIA® Jetson TK1 [2]	2.0 / 3.0	100 / 1000 MBit	yes
Raspberry Pi® 2 Model B [1]	2.0	100 MBit	yes
CompuLab CM-FX6 (SBC-FX6) [4]	2.0	100 / 1000 MBit	yes
ODROID-XU4 [3]	2.0 / 3.0	100 / 1000 MBit	yes

Table 2: Overview of interfaces of the tested ARM®-based platforms

For optimum results when using the Gigabit Ethernet interface, an MTU size (that is, size of the individual Ethernet packets) of 9000 bytes is to be recommended on account of the large data quantities of a camera system. Smaller sizes are also suitable, but lead to a higher CPU workload. The data sheets of the suppliers in question usually specify whether an Ethernet controller supports these so-called “jumbo frames”.

4 Software porting onto an ARM®-based platform

Existing software solutions for image processing can be ported onto an ARM®-based platform. This is possible with the Baumer GAPI Software Development Kit for ARM® processors. In this way, applications that have already been developed can easily be ported onto an ARM®-based platform without new developments. If the software has been used on a Linux® system thus far, software porting can be effected simply by using a different compiler. The porting of the software can be effected with cross-compiling as well as by using native compiling.

With cross-compiling, the creation of the software is carried out on a separate host system. This can be a significant advantage in terms of development speed, since appropriate powerful cross-toolchains are available. They all contain the necessary programs (compilers, linkers etc.) as well as the headers and libraries of the target system to create the ARM®-compatible software version. The tool chain of Linaro [5] has proved highly suitable here. The software thus created is then used on the actual target system and is reduced to the essentials.
Native compiling is understood to be the transmission of all source code files of the software onto the ARM®-based platform, so that the software is created directly on the platform. A tool chain must also be present there. As a rule, compilers for C/C++ and the relevant linkers are already contained in the operating systems of the ARM®-based platforms. If this is not the case, they can be installed subsequently. If the image processing software has been created on a Windows® system, it is necessary to adjust or adapt the specific system calls for a Linux® system.

5 Baumer GAPI SDK software package for ARM® processors

The Baumer GAPI SDK for ARM® processors contains all necessary components for integration and documentation. On the one hand it contains standard packages, with which the evaluation kits of different manufacturers can be used directly; and on the other basic packages allows in-house developments to be carried out.

The basic packages contain all of the necessary libraries and software components to allow the complete integration of GigE cameras in image processing software. Packages are available for hard-float and soft-float processors from the ARM® ARM7™ family. With these, flexible developments can be implemented on many different systems including Linux® operating systems. Tools for a display or a simple interface are not included. The packages were tested with the ARM®-based platforms listed in Table 3 and the appropriate Linux® operating systems.

The standard packages contain tailored and tested installation packages for currently available evaluation kits. These packages are tailored to the operating system recommended by the manufacturer of the ARM®-based board and serve to evaluate an industrial camera quickly and easily. The Baumer Camera Explorer visualization tool is also included, and allows the immediate startup of a camera on the selected ARM®-based board. With this, initial tests can be started easily and without any work or costs for development.

The following standard packages are available:

ARM®-based board	Operating system (OS)	OS version	Release Date
NVIDIA® Jetson TK1	Linux® for Tegra® (Ubuntu® 14.04)	R21.4	July 2015
Raspberry Pi® 2	Raspbian	Jessie	September 2015
CompuLab CM-FX6 (SBC-FX6)	Debian®	7.8	November 2015
ODROID-XU4	Ubuntu® 15.04	20150710	July 2015

Table 3: Standard packages for ARM®-based boards

The Baumer GAPI SDK for ARM® processors can be obtained by contacting Baumer Support: support.cameras@baumer.com.

For the installation and evaluation of individual standard packages and for various boards, separate Application Notes are still available from Baumer. These can be obtained through the Member Area of the website.

6 Summary

The market offers a wide and steadily increasing selection of powerful ARM®-based hardware platforms. Through innovations in the consumer sector, there will be more significant improvements in performance, allowing the increasing use of ARM®-based boards as alternatives to PCs for machine vision applications. Existing machine vision applications can be ported, developed and easily evaluated with evaluation boards by different manufacturers and an SDK like the Baumer GAPI SDK for ARM®-based platforms. The Baumer GAPI SDK serves as an interface between the camera and the image processing software, and is available ready for use for different boards. Individual, matching hardware solutions can be developed as a result of an evaluation.

7 References

[1] https://www.raspberrypi.org/products/raspberry-pi-2-model-b/
[2] http://www.nvidia.com/object/jetson-tk1-embedded-dev-kit.html
[3] http://www.hardkernel.com/main/main.php
[4] http://www.compulab.co.il/products/computer-on-modules
[5] http://www.linaro.org/

8 Authors

Torsten Wehner
Product Management

Martin Dödtmann

Baumer Optronic GmbH
Badstrasse 30
DE-01454 Radeberg
Phone +49 3528 4386 0
Fax +49 3528 4386 86

Baumer Group
The Baumer Group is one of the worldwide leading manufacturers of sensors, encoders, measuring instruments and components for automated image-processing. Baumer combines innovative technologies and customer-oriented service into intelligent solutions for factory and process automation and offers an unrivalled wide technology and product portfolio. With around 2,300 employees and 38 subsidiaries in 19 countries, the family-owned group of companies is always close to the customer. Baumer provides clients in most diverse industries with vital benefits and measurable added value by worldwide consistent high quality standards and outstanding innovative potential. Learn more at www.baumer.com on the internet.

Baumer
Passion for Sensors

Switzerland
Baumer Electric AG
P.O. Box
Hummelstrasse 17
CH-8501 Frauenfeld
Phone +41 52 728 1122
Fax +41 52 728 1144
sales.ch@baumer.com

Germany / Austria
Baumer GmbH
Pfingstweide 28
DE-61169 Friedberg
Phone +49 60 31 60 07-0
Fax +49 60 31 60 07-70
sales.de@baumer.com