No Martini, No Party

Image Processing Basics: Illumination

We are at the end of the first decade of the 21st century, the "century of the photon." Machine vision is an accepted technology on the factory floor in virtually all manufacturing industries and in a number of important non-industrial areas. But where are the groundbreaking innovations, the spectacular developments, the awesome achievements leading into new, unheard-of regions of knowledge and business?

In the past 10 years, we neither saw the equivalent of the landing on the moon nor of the flight over the Atlantic Ocean, and the invention of the Laser celebrated its already 50th anniversary this year. Instead of picking a single highlight, this article focuses upon a continuous development within the last decade, which seems to be quite unspectacular at first sight: the growing awareness of the fundamental relevance of lighting for machine vision.

No Illumination, No Machine Vision

An image processing system is bound to process only those features of a scene which are somehow illuminated. This statement seems to be trivial and represents by no means a new finding. A novelty, however, is the fact that everybody working in this field nowadays will be confronted with this piece of inevitable truth. As early as 1991, Hartmut Ernst in his excellent textbook [1] covers lighting in an own chapter, although on only three out of about 300 pages. A key passage reads as follows: "An important component for image processing is application-specific lighting. A good lighting of the scene to be captured often allows the use of simpler and thus faster algorithms for the evaluation of the image. In general, lighting will be optimized to achieve high contrast. Usually, minimizing shadows and reflections will also be called for." This advice is as important and proper today as it has been 20 years ago. Lighting should be used to enhance features of interest and to suppress unwanted structures. In this sense, lighting is a necessary and quite efficient step in image processing. Lighting by ambient light from natural sources will nowadays only be accepted when no alternative is available.

Further Development

Over decades, machine vision was primarily treated as "digital image processing" in most textbooks, putting emphasis on the algorithmic handling of the image data file. Filters, grey-level transformations and morphological methods where described in great detail. Even in 2005 a book on image processing [2], without any doubt one of the best in the field for introductory purposes, treated illumination in only one scarce sentence: "The actual process of image formation is often complicated and usually insignificant for image processing". On the other hand, in the same year the 6th edition of a standard-textbook [3] already featured main aspects of the interaction of lighting and objects on 35 (out of 600) pages. A textbook published in 2008 [4] takes great care to emphasise the importance of lighting as a system component for machine vision applications and dedicates a full chapter with 12 of about 300 pages to the topic, presenting valuable hints

and examples. And this year a major distributor of machine vision components has published a voluminous catalogue with about 300 pages [5], putting 20 pages in an application note and further 40 pages in product information on lighting technology, that is about 20% of the total volume. Here you may find the remarkable comment: "The choice of the proper lighting is crucial for the quality of the image acquisition and can strongly simplify the subsequent evaluation of the image. Often, however, the significance of the proper light source for an image processing system is underestimated. Finding the appropriate lighting is a demanding task".

What's the Problem?

Lighting – just a piece of cake? Light is a concept of human visual perception. Electromagnetic waves with wavelengths between about 400 nm and 700 nm are a sensory stimulus for our eyes and brain. For us, it is a matter of course to experience the brightness and chromaticity of our natural environment on a sunny day through our eyes. We may even read a newspaper at night in the desert with just the moon shining above, although the light intensity is several orders of magnitude lower than at noon on a clear summer day. Even at much lower light levels we can navigate and define objects, and many of us are not even aware of the fact that our color vision vanishes under these circumstances and "all cats are grey" in the night. Shadows and inhomogenities in our field of view usually will not significantly affect our ability to interpret the scenes in our natural environment. Even the tremendous variations of the spectral distribution of the natural light from the sun during the day does not catch our eyes, and we will see the white plastered facade of a house as a white surface, whether it is illuminated by the romantic red of a sunset or by the white sunlight at noon. The layman usually never will realize the tremendous pattern recognition performance of the human visual system. Only few professionals like photographers or interior decorators develop an intuition for these problems. Even senior machine vision systems engineers may be amazed when they become aware of the facts. The abilities of our human visual system seem trivial for us, and we instinctively expect the same performance from a technical system, tempting us to underestimate the relevance of lighting for machine vision applications.

A Professional Approach

Ten years ago, only few companies specialized in lighting equipment for image processing. Meanwhile, every trade fair in the field offers a broad spectrum of such products. Notably, several companies with a strong background in high-end optics joined this business, utilizing their competence in optical engineering and complementing their product range with LED-lighting-devices. Lighting nowadays is recognized as a profitable segment of the machine vision market and treated as a demanding engineering

task. In fact, the essential development during the last decade happened in our mind, since "the innovative manufacturers of machine vision systems became aware of the significance of lighting …" [6]. It is not by sheer coincidence that at the same time non-imaging optics became an additional feature in several professional tools for optical design. Lighting concepts for sports arenas or automobile head lights are nowadays designed and optimized with ray-tracing-tools. These methods can seamlessly be adapted to lighting systems for machine vision. Micro-optical heads for laser-diodes, e.g., provide structured lighting with defined circular, point- or line-patterns. LEDs with their compact form factor and their compatibility with standard electronics open up completely new concepts, which can only be exploited with optical design tools. For line-scan cameras, e.g., LED-line-lighting devices are available with programmable intensity profile. In addition, the long lifetime and the defined time structure of emission are important advantages for industrial applications. Even UV-lighting with LEDs is possible nowadays. The most important technical development within the last decade, however, is the general availability of sufficiently bright white LEDs. Shuji Nakamura, who basically invented these devices in 1993, was honoured for this with the Millennium Technology Prize in 2006 [7].

The Future

While light, strictly speaking, is limited to the region of human visual perception, the Silicon- and InGaAs-detectors of our standard-cameras are sensitive up into the near IR. In the upcoming years, the spectral distribution of lighting and the spectral regions beyond the visible range will receive more and more attention. The color rendering index of light-sources already is an important feature in color image processing, and several applications use NIR-imaging within the sensitivity range of Silicon-detectors. Light sources with programmable spectral distribution are already commercially available, and people become aware of the fact that spectral discrimination is not restricted to dispersive devices at the detector but may also be achieved by lighting. Spectacular leaps in technological development, however, are not to be expected. Believe it or not, innovation is a slow process. Even when triggered by enlightenment.

References

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