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Towards an ultra-low-power low-cost wireless visual sensor node for fine-grain detection of forest fires

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Abstract

Advances in electronics, sensor technologies, embedded hardware and software are boosting the application scenarios of wireless sensor networks. Specifically, the incorporation of visual capabilities into the nodes means a milestone, and a challenge, in terms of the amount of information sensed and processed by these networks. The scarcity of resources – power, processing and memory – imposes strong restrictions on the vision hardware and algorithms suitable for implementation at the nodes. Both, hardware and algorithms must be adapted to the particular characteristics of the targeted application. This permits to achieve the required performance at lower energy and computational cost. We have followed this approach when addressing the detection of forest fires by means of wireless visual sensor networks. From the development of a smoke detection algorithm down to the design of a low-power smart imager, every step along the way has been influenced by the objective of reducing power consumption and computational resources as much as possible. Of course, reliability and robustness against false alarms have also been crucial requirements demanded by this specific application. All in all, we summarize in this paper our experience in this topic. In addition to a prototype vision system based on a full-custom smart imager, we also report results from a vision system based on ultra-low-power low-cost commercial imagers with a resolution of 30×30 pixels. Even for this small number of pixels, we have been able to detect smoke at around 100 meters away without false alarms. For such tiny images, smoke is simply a moving grey stain within a blurry scene, but it features a particular spatio-temporal dynamics. As described in the manuscript, the key point to succeed with so low resolution thus falls on the adequate encoding of that dynamics at algorithm level.

Keywords: forest fires, surveillance systems, wireless sensor networks, automatic early detection, artificial vision, low-power sensors, vision algorithms.

1. Introduction

Wireless Sensor Networks (WSNs) (Akyildiz et al. 2002) constitute an enabling technology for the paradigm of pervasive computing (Weiser 1991). One of the most representative application frameworks of this paradigm is environmental monitoring. Typical scenarios are precision agriculture (McCulloch et al. 2008), forest canopy analysis (Tolle et al. 2005), volcanic studies (Werner-Allen et al. 2006), meteorological station networks (Barrenetxea et al. 2008) etc. In all these cases, the network nodes incorporate particular sensing capabilities according to the requirements of the application considered. These capabilities share a common feature: they provide scalar measurements, e.g. temperature, humidity or wind speed. Moreover, the data sampling rate is usually low or moderate at most, leading to a reduced amount of information to be handled locally by the nodes. These conditions significantly change when it comes to the in-node implementation of multimedia sensing (Akyildiz et al. 2007). Specifically, the implementation of vision hardware at WSN nodes is not a trivial issue at all since the visual stimulus implies to deal with a massive flow of multidimensional information. Taking into account the very strict power budgets allocated to the nodes, the mere capture and digitization of an image sequence could represent a significant percentage of their energy consumption.