Demo Abstract: Mountainview – Precision Image Sensing on High-Alpine Locations

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***Abstract*— We describe a novel optical sensor system designed for high-fidelity image acquisition in wireless sensor networks. The system uses precision optical equipment as well as a high-resolution imager yielding accurate observations - a prerequisite for many image processing techniques. In order to deliver the lifetime and durability required by long-term environmental monitoring campaigns we present a custom solution that is optimized to integrate seamlessly into a power efficient wireless sensor network. The imaging system presented is based on a state-of-the-art wireless digital SLR camera, that has been packaged, augmented with the necessary power supply, heater, system supervision and control to operate reliably under the most hostile and extreme environmental conditions.**

I. INTRODUCTION

The PermaSense project [1] strives for collecting geophysical data in the high-altitude environment of the Swiss Alps with a wireless sensor network (WSN). To this day, a WSN consisting of one base station and 16 motes has been successfully deployed on the Matterhorn at 3.500 meters above sea level and ambient temperatures down to -40°C since July 2008. In this deployment, simple analog and digital sensors representing properties such as temperature, humidity or electrical resistivity are sampled every few minutes. While this sensor data is highly valuable for the geophysical research of our joint project partner, there are contexts that require more complex data, e.g. fidelity and rates two or three orders of magnitudes higher than the current set of simple sensors.

In this demo we present a novel, high-precision wireless image sensor for the PermaSense project. This sensor allows to assess temporal variability in the snow cover as well as rock and ice movement with great detail. For the application of advanced image processing algorithms and a meaningful analysis of the image data gathered from the environment, the fidelity and optical precision are of the utmost importance. For this purpose a digital SLR camera is mounted in a ruggedized housing. The housing includes an optically corrected lens port, heating system, system supervision, power supply and integrated into our wireless sensor network infrastructure. The main challenges are reliability concerns, issues concerning power efficiency and the available energy supply, data throughput, image quality as well as flexibility in the deployment location to obtain an optimal field of view of the inspection site. The system design is optimized to operate on a very low duty cycle, i.e. with a few pictures per day. It should still allow for a flexible and quick wakeup upon the request of a user or another sensor.

II. SYSTEM CONCEPT

The general concept of our sensor system is depicted in Fig. 1. A Nikon digital SLR camera with interchangeable lenses is housed in a steel enclosure. A lens port, derived from an underwater still camera housing, using non-reflecting, optical glass opens the field of view for the camera. Since the anticipated data volume per image (∼11MB RAW, ∼6MB JPEG) by far exceeds the performance of any low-power, mote-based WSN the camera uses a dedicated WLAN link to transmit images to a base station. An additional heater allows to defog the lens port and heat the camera/lens to an acceptable ambient level. Since all three consumers consume considerable amounts of energy a power switch controlled by a low-power TinyNode sensor node allows to power-cycle the individual components when not in use. Effectively, this reduces standby power consumption to an acceptable minimum. Furthermore, the sensor node serves as an internal health indicator providing regular ambient temperature, humidity and battery fill levels. Depending on the intended application scenario the sensor system can either be powered from an integrated battery allowing to take a finite amount of pictures or by a solar system (solar panel, charger, rechargeable battery).

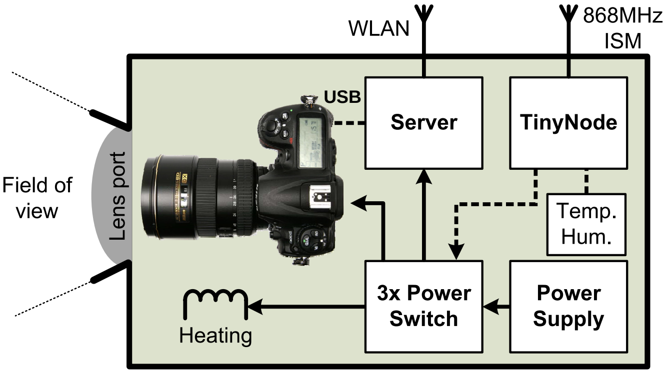

Fig. 1. The Mountainview sensor contains a professional digital SLR camera, a heater and an embedded computer with WLAN connectivity. Power consumption is controlled and monitored via a TinyNode sensor node. An adjustable mount supports different lenses and focal points for enhanced image quality.

III. IMPLEMENTATION

The Mountainview prototype is based on a Nikon D300 DSLR with a 12.3 MegaPixel image sensor. An attached Gumstix embedded computer is used for camera control. Adding a WLAN interface allows to control the camera, download thumbnails and full images over the Internet from a remote computer. A detailed power profile of the camera at startup and during image capture is given in Figure 2. The camera consumes an average of 220 mA with peak currents up to 3 A at 9V. The power consumption of the embedded computer is in a similar range, measured at 3 W average when connected to a WLAN access point. Alternative WLAN microservers, e.g. optimized for long-range point-to-point directional links are known to require even more power with about 10-20W average power consumption.

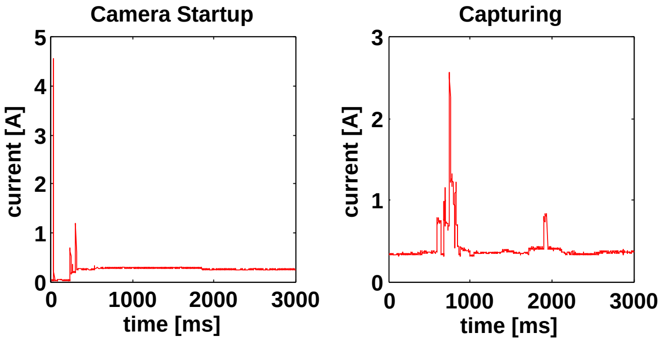

Fig. 2. Current draw during camera startup (left), image capture and storage.

It is thus necessary to power cycle all power hungry consumers and only enable them when their function is required. By using a TinyNode sensor node running a custom version of the ultra-low power application Dozer [2] the power consumption is reduced to a mere 0.148mA. By sending a broadcast packet over the wireless sensor network the user can control when and for how long to enable heater, camera and embedded computer. The monitoring of temperature, humidity and battery fill levels is not only a necessity while operating the camera/heater but also when the system is in long sleep phases to alert in case of water ingress. A simple timer to wake up the system, transmit an image and go back to sleep is not an option as it would (i) limit the flexibility/reactivity of the system and (ii) lack the online system supervision that is critical to successful long-term environmental monitoring, especial in the environmental extremes of PermaSense.

IV. RELATED WORK

Depending on the application, the desired geophysical data can also be gathered by aircraft or satellites [3], [4]. However, there are certain constraints concerning costs, availability, spatial resolution and applicability of remote sensing techniques. For the price of a smaller covered area, our approach focuses on a high spatial resolution and more flexibility as the later application is virtually only dependent on the number and location of the installed cameras.

Sharing the same motivation, Kodak DC20 cameras with a timer-based trigger mechanism for automatic image gathering are used in [5]. In contrast, our work first of all offers a much higher image quality concerning image resolution and optical system used. Additionally, our prototype allows remote control and near real-time data access.

Several projects in the WSN field have proposed the usage of image sensors for sensing, control and verification purposes. These often low-resolution CMOS camera modules or webcams are directly attached to sensor nodes [6], [7]. These applications have quite different requirements concerning image quality, installation location, density and durability when compared to our project.

V. CONCLUSIONS AND FUTURE WORK

The current progress of our work promises a great tool for geophysical and possibly other scientific experiments at a new level of detail and interactive control for reasonable costs. While our current experiments have only been carried out in our lab, we are intending to deploy our prototype on the Matterhorn field site. A detailed assessment of the optimal duty cycle is currently under investigation. However, it is likely to depend much on the actual requirements of system operation at the field site as the main consumers of power (heater, WLAN) depend on the actual circumstances at the site. Future work encompasses the use of smaller/different sensors for triggering the main sensor and 3-D modeling using multiple cameras.

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