Bridging the Last Gap: LedTX - Optical Data Transmission of Sensor Data for Web-Services

Philipp M. Scholl
ESS, TU Darmstadt.
Hochschulstr. 10
64283 Darmstadt
scholl@ess.tu-darmstadt.de

Nagihan Kücükyildiz
ESS, TU Darmstadt.
Hochschulstr. 10
64283 Darmstadt
nagi@ess.tu-darmstadt.de

Kristof Van Laerhoven
ESS, TU Darmstadt.
Hochschulstr. 10
64283 Darmstadt
kristof@ess.tu-darmstadt.de

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Abstract
Data transmission from small-scale data loggers such as human activity recognition sensors is an inherent system's design challenge. Interfaces based on USB or Bluetooth still require platform-dependent code on the retrieval computer system, and therefore require a large maintenance effort. In this paper, we present LedTX, a system that is able to transmit wirelessly through LEDs and the camera included in most user's hardware. This system runs completely in modern browsers and presents a uni- directional, platform-independent communication channel. We illustrate this system on the UbiLighter, an instrumented lighter that tracks ones smoking behaviour.

Author Keywords
optical, wireless, data transmission

ACM Classification Keywords
B.4.1 [Hardware]: Input/Output and Data Communications; J.3 [Computer Applications]: Health

Introduction
Long-term monitoring of human subjects has found a number of interesting applications in recent years. Electronic diaries, via ambulatory assessment, for patients undergoing psychological treatments [8], gesture control for mobile phones [1] or a multitude of other applications

[7] are just a few examples of the monitoring needs. All of those systems need to communicate with a PC application that in turn analyses the recorded data to give additional information about the monitored activities. Where delayed access to this data is a possibility, a USB connection (or other wired system) is typically used instead of a wireless connection. Both wired and wireless transmissions however share the problem of requiring some software on the PC that retrieves this data from the device. A designer of such a monitoring system then faces the challenge of making sure that the retrieval software works cross-platform on multiple Operating Systems, an effort not to be underestimated, especially for successive iterations of research prototypes.

In this paper we introduce a system that works completely in an HTML5-compliant webbrowser, which allows to transmit data from LEDs via a webcam, nowadays often found in laptops, smart-Phones and other computing accessories. We show the applicability of this approach on the example of the UbiLighter, an instrumented lighter that records the smoking behaviour of its users. The data will be sent to a webbrowser to generate visual feedback of the user's smoking behaviour. This drastically reduces the amount of time spent in developing a retrieval and analysis software and bridges the last gap to retrieve the gathered data in a platform-independent way. Furthermore this enables an almost instant feedback for people using an easily deployable system for in-field, long-term studies.

Related Work

Data transmission with visible light and a commodity camera has provided the means for remote identification and localization of sensors attached to factory machinery in [3]. The camera integrated into a tablet computer has been used to provide a "see-through" image of the scene augmented with the sensor values, in which sensors have been identified through active optical markers. The optical identifier has been encoded by a Hamming sequence transmitted at 50Hz.

The μPart configuration tool, presented in [2], follows the same motivation as this paper - computer software for custom devices present a large effort to be maintained. The configuration of the μPart, a miniature uni-directional wireless sensor node, was achieved by exploiting the included light sensor to transmit data via a blinking area on a LCD screen. Reconfiguration could therefore be done with a single platform-independent program running in a webbrowser.

Bi-directional optical data-transfer using only LEDs has been shown in [5]. An RS-232 like protocol has been employed. More recently data transmission via the modulation of headlights in indoor environments has been shown to achieve data-rates of up to 100Mbps [6].

System Design and Implementation

In this section we describe the system design for transmitting data from the UbiLighter. The data we want to transmit are timestamps of the times when the lighter has been used to light up a cigarette. This is achieved by blinking the two included LEDs on the UbiLighter and analysing the video stream recorded by a webcam on a PC. The LEDs blinking patterns contain the differentially compressed timestamps.

This compression is necessary because of the low achievable throughput of this solution. The timestamps are transmitted differentially, i.e., after a priming timestamp has been send, only the difference to the last transmitted timestamp in multiples of 6-minutes is transmitted. This 6-minute interval is assumed to be the minimum difference between smoking incidents and encoded as an unsigned 8-Bit integer.

An overview of the communication setup can be seen in Fig. 1. A commodity webcam records a video stream of the LEDs embedded in the UbiLighter. Since this simplex optical channel will be subject to transmission errors, we followed [3] to guard the transmission with the forward-error correcting Hamming code. The recorded video frames are split into images which contain only the color of the two LEDs, and a transmitted bit is detected with the help of a Blob detector. If there is a blob of the specific color a '1' has been transmitted and its absence will detected as a '0'. These signals are the passed into a demodulator for the Hamming encoded data. All of these components are implemented in Javascript and besides a compliant webbrowser, no additional software needs to be installed on the user's PC.

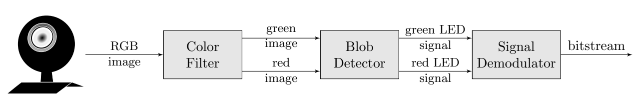

Figure 1: Data reception pipeline, the webcam records a live-stream of the red/green LED on the UbiLighter, which is passed into a color filter and split into a red/green picture. A blob detector finds the LED in each video-frame and passes that information into the signal demodulator which returns the bitstream.

Theoretical Transmission Bandwidth
The achievable transmission bandwidth largely depends on the capture frame rate of the used webcam. Typically frame rates of $\lambda = 30fps$ are possible, but the sampling process is limited by the Nyquist-Shannon theorem to a sample rate of $\frac{\lambda}{2}$. The number of usable LEDs is another important factor, in our case $k = 2$ bits can be transferred in parallel. Furthermore the rate of the error coding has also an influence on the amount of transmittable bits, we deliberately chose a (7,4)-hamming code, which results in the rate $R = 0.571$. Putting these factors together our theoretical transmission bandwidth can be calculated as $R * k * \frac{\lambda}{2} = 17.13bps$. Alternatively a CRC-8 could be used, which would only allow to check for an error but has the advantage of a higher encoding rate ($R = \frac{8}{9} = 0.88$). A CRC-8 based transmission would allow for a transmission rate of up to $26.4bps$.

Javascript-Based Data Reception
The implementation of the data reception pipeline (Fig. 1) is based on Javascript and the getUserMedia [4] standard for accessing the webcam. It is executable on most current webbrowsers without any additional software installation.

The data transmission is started by accessing the reception website and pushing the button on the UbiLighter three times in quick succession. The UbiLighter is then faced towards the webcam and a synchronization message is sent repetitively for a 10-second interval. This message contains identification information and the number of to be transmitted bytes. Afterwards the data/timestamps are transmitted. A successful transmission is acknowledged by the user pushing the button. Bits are transmitted by turning the LEDs on and off (amplitude modulation) with a frequency of half the sampling rate of the webcam.

Each video frame on the reception part will first be color-filtered, in order to get a camera image of each LED. A blob detector, which extracts the area with most co-located pixels, is then used to retrieve the status of the LED. If no blob can be detected a '0' has been read, if a blob was detected a '1' has been transmitted. This

Figure 2: The system in use, the UbiLighter is sending data to the Javascript reception pipeline via the LEDs and webcam.

information will enter the signal demodulation, where the bitstream is checked with either the Hamming code or the CRC-8 check. The decoded information has then been successfully transmitted from the device to the PC and is displayed to the user on the visited webpage. After that this data can be uploaded to some remote server for further analysis or directly analysed in the Javascript program.

Conclusion

We have presented LedTX[1], a system that enables uni-directional wireless data transfer from monitoring sensor devices. Albeit our solution does not offer a great bandwidth, it offers an installation-free, platform-independent way of data transmission that can be easily connected to webservices, by running completely in a webbrowser. For future work the bandwidth can be increased by using additional LEDs, or encode information in colors generated by RGB LEDs or miniature displays.

[1]Code available at http://www.github.com/pscholl/ledTX.

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