

Network based real-time control of a laser show projection system

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Abstract — This demo proposal deals with a live demo of a control system running as software on a laptop, controlling a laser show projection interface which is connected via an UDP/IP based network (e.g. using Ethernet and/or Wireless LAN). The programming and research work in this context is being carried out in the Laser & Light Lab at the Institute of Computer Science IV in the context of lab work in undergraduate student education. Basic goal of the lab work is to develop own Linux-based software and to carry out performance studies of the system.

Keywords – network-based real-time control; laser projection

I. INTRODUCTION & MOTIVATION

Laser show systems can be considered to be among the most visible applications of lasers and probably the most entertaining ones (cf. [3], [4]). A laser projector emits a laser beam of single color (typically red, green or blue) or a mixed-color beam, where several laser modules emit laser beams of different colors, which are mixed by dichroitic mirrors to a single beam. E.g. red + green modules with analogue modulation of the laser intensity can generate colors in the spectrum of red – yellow – green, a **three-color laser system** with red, green and blue (RGB) theoretically is **able to generate all colors of the RGB-spectrum** (including white in a composite way).

The single beam will be redirected in X- and Y-orientation by two moving mirrors which are mounted to a galvanometer each (so called “**laser scanners**”). The movement of the scanners will be controlled by a hardware driver, typically connected to a laser control interface device, which in turn is connected to a computer. The software on the computer controls the movement of the laser beam forming a kind of picture, as well as the timing of a sequence of “laser picture frames” and as such the sequence of a whole laser show. If the movement of the laser beam is fast enough (limited by the capabilities of the mechanical galvanometers and its electronic hardware drivers), a **steady picture** becomes visible **without flickering** of the repeating movement path of the laser beam. Depending on the laser interface hardware, the laser software has to deal with detailed timing of laser beam redirection/scanning (which meanwhile is out-dated) or with timing on a per-laser-frame basis, where detailed timing of

laser beam scanning on a per-point basis is performed by a microprocessor in the laser interface.

Two kinds of laser shows can be distinguished: With a **graphic show**, the laser beam forming a picture is directed onto a projection screen (or wall). The goal of this kind of show is to present some kind of “content”, e.g. a comic strip, text or logo display or any other kind of (animated) graphic projection. A sample is shown in figure 1.



Figure 1. Example of a laser graphic projection (pictures taken by University of Bonn in the Laser & Light Lab [5])

The second type of laser show is a so called **beam show**. Here, the beam is emitted from the laser projector in the direction of the spectators. Artificial fog is typically used to visualize the laser beams in the air, allowing for a three-dimensional perception of the generated laser figures by the spectator. The projected figures typically are geometrical shapes, e.g. like a circle generating the impression of a 3D tunnel. The principle of laser beam visualization with fog is depicted in figure 2.

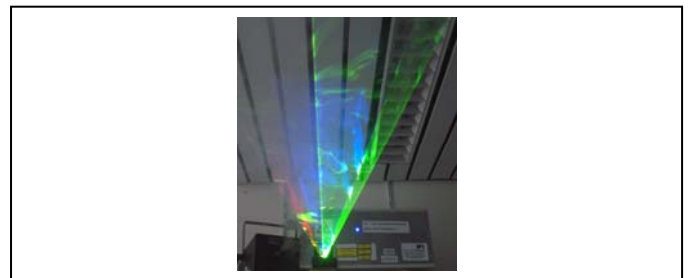
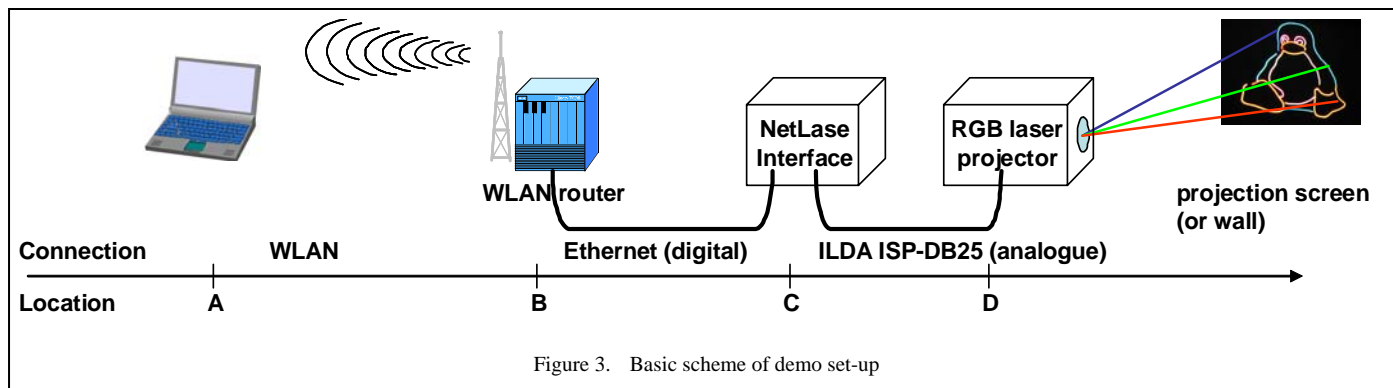


Figure 2. Example of a laser beam projection with fog visualization (pictures taken by University of Bonn in the Laser & Light Lab [5])

The **International Laser Display Association (ILDA, [2])** has defined several relevant standards for the set-up and



operation of a laser show system. The **ILDA Image Data Transfer Format** defines the way on how to save and transfer laser images and sequences of laser images (useful for laser show software). Furthermore, the **ILDA Standard Projector (ISP)** defines some hardware configuration, among others the **ISP-DB25**, a DB25 connector and signal specification for the cable connection between an ILDA compatible laser projector and a laser control interface (which is connected to a computer). The ISP-DB25 contains the X- and Y-signals used by the laser scanners to generate a laser picture by (mechanical) redirection of the laser beam. Although the **ISP-DB25 uses symmetrical or differential signal levels** for the X- and Y-signal (on two wires each), it uses an **analogue transmission of the signals** which is subject to attenuation or electrical interference over long distances. For a set-up of a laser system in a large area (like a trade show hall, a discotheque, a theatre, ...) the long distances might cause problems for the analogue transmission, possibly leading to degradation of the projected picture quality (apart from the X- and Y-signals also the color modulation for a RGB-system is transmitted as analogue signals in ISP-DB25).

The development of a **network-based laser projector interface** already started a few years ago (e.g. documented in [1]), commercial products on this became available in recent years (e.g. the so called NetLase interface, manufactured by [7] for own integration into a laser projector system; or the “Infinity ShowLaser” projector manufactured by [6]). The advantage of a laser system set-up with network-based control is the **digital transmission of the relevant information** (here: a full laser picture frame with a sequence of X/Y-coordinates and all necessary RGB color information). The laser projector interface might be integrated into the laser projector (i.e. analogue signal transmission only within the projector itself) or as a stand-alone interface using a short ILDA ISP-DB25 connector cable to the projector and covering the possibly **long distance to the laser show control computer via the network**.

Ethernet or Wireless LAN may be used as (digital) networking technology, only limiting the possible distance by characteristics of the technology (e.g. by communication range of Wireless LAN; by cable length limits of Ethernet, possibly extendable using repeaters/switches). However, **using a digital network may also cause challenges or limitations**. First of all, the communication protocol between laser show software/software drivers and the network-based laser control interface need to be designed properly (this e.g. for the NetLase

device [7] is given by the implementation of software drivers and an FPGA implementation on the hardware interface). Secondly, the **performance of the network** itself may have limiting factors (e.g. bandwidth), as the control of a laser show via the network is a real-time application similar to video-streaming (here: demand on specific bandwidth for continuous transmission of laser picture frame data of the sequence of a laser show as well as demand on the round-trip-time for some application specific control handshake).

The **Laser & Light Lab** [5] of the Institute of Computer Science IV at the University of Bonn has been set up to support teaching activities of undergraduate lectures of practical computer science. It builds on basic lectures in the area of low-level and machine-oriented computer science, including a one-semester lecture on computer system and network programming with a high degree of practical work.

Main topic focuses of the lab work are:

- **Communication** in a distributed system (sockets, I/O multiplexing, Threads, ...)
- Control of **externally connected hardware** (via parallel port, USB, TCP/UDP/IP network)

The external hardware includes a light controller and several light effect devices according to the DMX standard (DMX-512, Standard **D**igital **M**ultiple**X**ed, acc. ANSI E1.11) and several **full-color (RGB) laser projectors** with a control connection according to ILDA standard ISP-DB25 (as mentioned above).

For interfacing to the computer to run the laser show control software the lab has parallel port interfaces (EPP – enhanced parallel port; meanwhile somewhat out-dated for laser interfaces), interfaces via USB (Universal Serial Bus) and via a TCP/UDP/IP network (NetLase interface, [7]). To demonstrate the capabilities of professional laser show software, the lab runs some Microsoft Windows PCs with a selection of up-to-date professional laser software. However, the goal of the lab work for the participating students is to get own experience in programming the software and the interfaces for laser projector control on Linux-based systems.

II. SCOPE AND SIGNIFICANCE OF THE DEMO

The demo at LCN 2009 intends to show the laser show projection system (hardware and software) and some results of the lab work carried out in the Laser & Light Lab. The focus of

the demo set-up will be on the **network-based control interface**. The set-up of the laser-projector will be for a laser graphic show (cf. figure 1), which is similar to a set-up of a LCD/video projector used for other presentations).

Figure 3 shows the basic scheme for our intended demo set-up. The locations of laptop (with laser control software), WLAN router, NetLase interface and laser projector are marked with A, B, C, and D respectively. As described in section I, it is beneficial to keep the distance C – D low due to the analogue signal transmission in the ILDA based DB25 cable. For the connections A – B and B – C digital networks are used, in this case connecting the laptop to a Wireless LAN router, which in turn is connected by an Ethernet cable to the NetLase interface. In principle, the distance between A and C might be arbitrary long, limited by the specific networking technology.

For the demo set-up at LCN 2009, we do not need long distances to present features and challenges of the network-based control of the laser interface. The available bandwidth may easily be varied by adjusting the WLAN data rate in the WLAN router (according to IEEE 802.11g from 1 Mbit/s to 54 Mbit/s) or by injecting background traffic into the network.

The goals of the demo are:

- to demonstrate the **general operation** of the laser projection system with network-based control
- to present own **software on a Linux system** to control the laser projector over the network
- to demonstrate **laser safety principles** in case of network failure or crash of the controlling software/host
- to demonstrate **bandwidth limitations** with several network-based laser interfaces (emulated) or in presence of background traffic in the network

Upcoming and future work in the Laser & Light Lab on the topic include performance analysis for several network-based laser interfaces in the same network, analysis based on traces from real operation of a single network-based laser projector interface as well as measurements in our lab network of the Laser & Light Lab (probably by emulation of several network-based interfaces in the same network). Currently, there are no scientific publications available on the topic (or only few without direct relation). Depending on the outcomes of our work, it is intended to further publish results or experiences gained from the network-based laser control as an application case for real-time time control in a local area network.

III. CONCLUSION

The proposed demo intends to present some practical work carried out in the Laser & Light Lab of the Institute of Computer Science IV at University of Bonn. The network-based control of a laser projection system is an up-to date topic in the application sector of laser show systems. In relation to the research topics covered at LCN in general, it is an interesting application of real-time communication in a local area network.

The work on network-based laser control is quite new in our lab. Nevertheless, the demo intends to present the general set-up of such a system, some early programming results carried out in the lab (on Linux-based systems) as well as pointing on some limitations or challenges to operate such a system in a local network. Future work will comprise both analysis and measurement of the system performance in a single network with several control interfaces. Further publications are envisaged.

IV. ACKNOWLEDGEMENTS

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