Integrated visualization of installation plans and installation costs of fiber optic networks

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Abstract

Due to the increasing use of the Internet, there is a growing demand for expanding fiber optic networks. However, the cost-effective design and installation of fiber optic networks can be labor-intensive. Typically, computer-aided planning is used to support the design of fiber optic networks, i.e., the drafting of cable installation plans and the calculation of installation costs. Cable installation plans are usually illustrated on digital maps, while costs are typically listed separately in cost units. Hence, the detachment of cost calculations from cable installation plans impedes the efficient and accurate analysis and optimization of installation costs. To facilitate the analysis and optimization of installation costs, the cost calculations must be integrated into the installation plans. This paper presents a modular software system for computer-aided fiber optic network design, enabling automated cost calculations within cable installation plans. Instead of monochrome installation plans, typically employed in digital maps, a coloring schema is used as an indicator of installation costs. The proposed approach is validated through a case study of the design of a fiber optic network for a residential area. The validation case study showcases the automated calculation of an installation plan of a fiber optic network with integrated installation costs. The colored installation plans enable the identification of the most expensive cabling sections within the residential area, facilitating the cost-efficient design of fiber optic networks.

1 Introduction

The increasing use of the Internet has been raising the need for growing data exchange [1]. While the existing capacities of telecommunication network backbones are sufficient to support future Internet traffic, significant improvements of the access networks are necessary [1, 2]. New fiber optic networks need to be installed to enable next-generation high-speed Internet access [3]. In conventional fiber optic network design every mailing addressable building within a planning area is interconnected, in an approach referred to as “fiber to the building (FTTB)”. However, the installation of fiber optic networks is expensive and detailed design is required to reduce installation costs [4]. The design of fiber optic networks is supported by several computer-aided planning software packages, while the detailed planning of fiber optic networks is facilitated by the geospatial positions of buildings and streets [5, 6]. Typically, the outcome of computer-aided fiber optic network design is cable installation plans and cost calculations.

A cable installation plan is a technical representation of cabling paths and connections. In general, monochrome colored lines are used for representing cable paths in cable installation plans, while coloring is used to differentiate and to label individual wires (or individual fibers) within a cable [7]. In addition, coloring is used to symbolize the affiliation of each cable to various distributors within the installation plan. However, cable installation plans on the one hand are usually presented to the planner separately. With cable installation plans being detached from cost calculations, it is difficult for the planner to analyze the most expensive cabling paths.

In this paper, a modular software system for computer-aided fiber optic network design is presented. The modular software system contains a module for integrated visualization of installation costs into cable installation plans, hereinafter referred to as “cable installation plans with integrated installation costs”. The installation costs of every cable path are indicated by different colors. The RAG system (red, amber, green) [8], a flexible approach also known as “traffic light rating system”, is employed to indicate the installation cost within an installation plan for analyzing the most expensive cabling paths.

This paper first describes the modular software system implemented to support fiber optic network design. Then, the visualization module of the software system is illuminated. Next, a validation case study of the fiber optic network design of a residential area using the proposed software system is presented. Finally, the results of the case study, as well as future research directions, are discussed.

2 A modular software system for fiber optic network design

The modular software system is designed to perform three main tasks: 1) data acquisition, 2) geospatial analysis as well as planning of fiber optic networks, and 3) data visualization and data export. Therefore, the system is
divided into three subsystems; the input subsystem, the processing subsystem, and the output subsystem. The subsystems contain several modules, as shown in Figure 1.

The **input subsystem** includes modules to collect input data from existing (mainly open-source) data sources, such as “OpenStreetMap”. One module is allocated to each data source and is deployed to download and to unify the data. Only data relevant to fiber optic network design is stored and processed by the modular software system.

The **processing subsystem** contains modules for geospatial analysis (“analysis module”) and for fiber optic network planning (“planning module”). The analysis module, as shown in Figure 1, processes the data from the input subsystem to generate a routing graph of existing streets and ways within a planning area. The routing graph contains information about geospatial positions and the assumed installation costs, calculated based on site characteristics (e.g. ground surface and soil). The planning module uses the routing graph, generated by the analysis module, to perform cost optimization of fiber optic network designs. The fiber optic network calculated by the planning module consists of several cable paths. A cable path consists of sections, similar to the links within the routing graph, and the respective installation cost. The installation costs of each section are calculated, essentially, by adding the costs for cabling and the costs for trenching (forming of a trench into the ground to lay the cables of the network) [9-11]. Trenching costs per section are only summarized once, because one trench can hold multiple cables. The processing subsystem provides all data relevant to the designed fiber optic network, i.e. the cable paths, the cabling sections, and the associated installation costs.

The output data of the processing subsystem is used within the visualization module of the **output subsystem** to generate installation plans with indicated installation costs. The output subsystem comprises different modules designed for user interaction, including modules for data export as well as modules for visualizing the data generated by the analysis module and the planning module.

### Figure 1
Subsystems of the proposed software system for fiber optic network design

**3 Visualization of a cable installation plan with integrated costs (visualization module)**

The objective of the visualization module is the geospatial representation of installation plans with integrated installation costs. Integrated cost visualization enables the cost-optimized design of fiber optic networks. To enhance the efficiency and accuracy in design, the installation costs must be indicated within the cable installation plans as clearly as possible.

As mentioned previously, the data fed into the visualization module is the calculated fiber optic network consisting of cable paths, cabling sections and the associated installation costs for cabling and trenching. Representing a clear and intuitive approach to indicate the installation costs within installation plans, color coding is proposed in this study. Typically, color coding is applied in temperature maps of weather reports. Therein, temperatures between -20 °C and +40 °C are usually indicated by different colors (i.e. violet, blue, green, amber, red) and their respective gradations. In temperature maps, due the amount of information included, a large number different colors are used. However, such a concept would be impractical for the clear and intuitive cost indication in cable installation plans of fiber optic networks. Therefore, in this study, the so called RAG (red, amber, green) rating system, also known as traffic light rating system, is implemented. The RAG rating system is used in various disciplines, such as project management and nutritional sciences, as a “status indicator” [12, 13]. The RAG rating system indicates the relation between an actual value and a reasonable maximum value using the colors red (for high), amber (for medium) and green (for low). The users of the RAG rating system define the reasonable maximum value and the thresholds from color variation.

In the approach presented herein, the RAG rating system is used to indicate the relationship between the installation cost per meter and the recommended maximum installation cost per meter. The recommended maximum
installation cost per meter and the thresholds are defined by the planner according to the characteristics of the planning area. For example, the total installation cost divided by the total length of the fiber optic network results in average cost per meter. The average cost per meter is used as recommended maximum installation cost. Exemplarily, the threshold for green/amber is set to 100% and the threshold for amber/red is set to 200% of the recommended maximum installation cost. In other words, all cabling sections in a planning area with installation cost below the recommended maximum installation cost are colored green. Sections with installation cost between 100% and 200% of the recommended maximum installation cost are colored amber, and sections with installation cost more than 200% of the recommended maximum installation cost are colored red.

As shown in Figure 2, the visualization module is implemented as an interface between data processing and visual representation. Once the data from the planning module is entered, the visualization module calculates the average installation cost, which is denoted as the recommended maximum installation cost. Then, depending on the installation cost data, the cable sections are colored according to the color defined by the thresholds. The processing ends with serializing all sets of data of the cabling sections to a JSON (JavaScript Object Notation) file. The JSON format is a widely used, user-readable data format for data exchange over the Internet [14].

4 Application example

The modular software system is validated by a case study of the fiber optic network design of a residential area. The area is suburban, including buildings and streets, as shown in Figure 3. The map and the geospatial data for fiber optic network planning are taken from OpenStreetMap. The fiber optic network design is automatically calculated by the modular software system. Every mailing addressable building within the planning area is connected to the fiber optic network, which is installed along the streets. In Figure 3, the blue polylines drawn into the map represent a monochrome cable installation plan of the designed fiber optic network without integration of installation costs.

Figure 3 Monochrome installation plan of a residential area without visual representation of the installation costs

Figure 4 illustrates the cable installation plan with integrated installation costs of the planning area, as calculated by the software system, consisting of red, amber, and green sections. The green lines represent cabling sections with low, i.e. favorable, installation cost (below the average installation cost). The amber lines represent cabling sections of medium installation cost (between 100% and 200% of the average installation cost). Finally, the red lines represent cabling sections of high, i.e. unfavorable, installation costs (more than 200% of the average installation cost). Cost optimization priority is given to the red-colored cabling sections, being the most expensive cabling sections.
The following discussion focuses on the optimization of the fiber optic network design. In Figure 5, the connection to the blue-marked building is highlighted, being identified by the cable installation plan with integrated installation costs as an expensive connection. Figure 6, by contrast, shows the cable installation plan with integrated installation costs of a cost-optimized fiber optic network for the marked building. In the optimization procedure, the fiber optic network connection between the building and the street has been changed from the street left to building to the street right to the building. As a result, spending little more for connecting the building with the fiber optic network (approximately 5 m), significantly reduces cabling along the streets (approximately 35 m) and, thus, the installation cost of the designed fiber optic network.

5 Summary and conclusions

The need for efficient and accurate fiber optic network design has been discussed in this paper. The missing link between the visual representation of cable installation plans and cost calculations has been established. An approach for integrating cost calculations into cable installation plans has been proposed and implemented into a modular software system. The combined visualization of installation plans and cost calculations has been accomplished using the RAG (red, amber, green) rating system. A case study has been presented to validate the implemented visualization approach. From the case study, it has been proven that integrating installation costs into cable installation plans facilitates not only a clear and intuitive visualization of installation costs, but also the cost optimization of fiber optic networks. In the case study, the cabling within a part of the residential area, which has been identified through the visualization module as very costly (“high installation costs”), could be substantially reduced from 35 m to 5 m, entailing a significant cost reduction of the fiber optic network.

6 References


