A Study on Optimization for Thermal Inspection method of Power Cable and Joint in Underground Tunnels using Autonomous Mobile Robot

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ABSTRACT

This paper presents a mobile robot equipped with 3D LiDAR and depth cameras which autonomously patrols underground tunnels and automatically stops at every cable joint. It is equipped with a hard-mounted lifting device with thermal and optical cameras, used to acquire thermal and optical images for the three transmission line phases individually. Furthermore, in the developed RCMS (Robot Control & Monitoring System), it recognizes trained images of cables and joints through a deep learning algorithm. It then extracts thermal images of cable ends and joints through an image processing algorithm based on OpenCV software, and diagnoses the difference between the highest temperature cluster and the mean temperature.

KEYWORDS

Underground Transmission Line; Cable; Joint; Thermal Imaging Inspection; Autonomous Mobile Robot; Deep Learning; OpenCV; 3D LiDAR; Image Processing;

INTRODUCTION

Since the 1980s, underground power transmission tunnels have been being widely constructed to prevent fires and other permanent failures that may occur due to natural disasters, and they are gradually reaching their life expectancies [1]. Safety accidents due to aging are likely to occur more frequently in older utility tunnels. In other words, it can be fully expected that the probability of occurrence will inevitably increase as the aging progresses. Therefore, a practical way to protect and safeguard workers while maintaining a stable supply of electricity without unexpected accidents, is to safely manage them through periodic inspections of underground facilities. However, since conventional inspection methods rely on skilled technicians with sufficient experiences, the accuracy of the diagnosis may be reduced due to the lack of objectivity in determining the results.

According to the standards for underground transmission operation in Korea Electric Power Corporation (KEPCO), scheduled maintenance requires to verify the surroundings of transmission lines once every month, and inspects thermal images of cables and joints twice every year. For the conventional method comprising thermal imaging inspection of cables and joints, the technician selects several points horizontally in the center of the cable joint, and calculates the temperature difference between the highest and the lowest point to determine whether the cable joint is an abnormal or not. In this conventional method, it is difficult to distinguish noise from normal data. In order to solve the problems of conventional thermal imaging inspection, this paper proposes an optimized method for thermal imaging inspection of power cables and joints in underground tunnels using autonomous mobile robots.

This paper is organized as follows. After an overview of the robotic system, basic tasks, acquisition task and detection tasks are introduced in section autonomous mobile robot, while diagnostic tasks and field test are detailed in section robot control & monitoring system. Conclusions are drawn in last section.

AUTONOMOUS MOBILE ROBOT

Inspection robots are usually utilized in unpredictable and extreme environments, such as mining tunnels [2-6], road tunnels [7,8] and utility tunnels [9-12]. In case of underground power transmission tunnels, a notable example of using surveillance cameras is using a rail-mounted system [13]. It drives along rails installed on the ceiling, and visual inspection is performed remotely using an optical and a thermal imaging camera mounted onto a PTZ translation stage. However, not only does rail installation cost a lot, but also wheel slip and corrosion occurs in humid environments. Therefore, in order to solve these operating limitations, an autonomous mobile robot with automatic inspection was developed.

Overview of the Robotic System

This section describes the architecture developed for an autonomous mobile robot system. The component layout, depicted in Fig. 1, shows each part of the system. First, the mobile robot autonomously patrols the tunnel according to the path plan, and collects PCD (Point Cloud Data) and optical/thermal 360-degree videos. As the mobile robot charges, these collected data are transmitted to the office via a docking station installed underground. In addition, the RCMS is developed to enable remote control and real-time monitoring of the connected robot, and it is configured to perform diagnoses such as power facility and structural inspections based on the collected data.

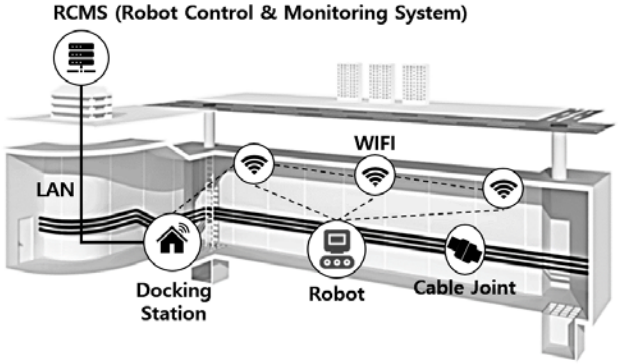

Fig. 1: Schematic diagram illustrating the system architecture