Ohio Department of Transportation Research Project Fact Sheet

STAR In-Road Electric Vehicle Charging for Parked Vehicles

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The Problem

The global electric vehicle (EV) market is forecasted to grow by 24.3% till 2028 constantly. However, the development in charging infrastructure is still lagging behind that, hindering the EV's widespread application, i.e., 30 million chargers are still needed to support the existing EV demand. Also, based on the survey by Witricity, 86% of EV owners are highly interested in wireless charging for parked vehicles, making it the 3rd most wanted feature in EVs. Here, we aim to design an over-the-pavement "inductive wireless charging ecosystem" for a fleet of autonomous electric vehicles (AEVs). The project's objectives are 1) design a wireless charging station that allows charging AEVs in the parking lot to increase efficiency, eliminate the need for individual charging wires for each EV, turn the passive parking time into a productive time, and increase the autonomy of charging process, 2) suggest the communication system between charging stations and AEVs (charger reservation system), the interaction between charger and AEVs, and safety. This proposed technology is necessary to implement a fleet of fully automated shuttles for the future generation of smart cities to connect people to the workplace, health centers, and recreational sites efficiently and with less carbon footprint. It also provides a safe charging technique for extreme climatic conditions (heavy snow and rain), which pose significant importance due to the climate of the state of Ohio.

Research Approach

We used Open3D software (an open-source library for point cloud data processing in Python) on the KITTI dataset to develop an in-house labeling software to mark the location of wireless charging stations on the HD maps. Also, the Apollo environment was used with our code to check our code's functionality.

Also, a comprehensive review of standards, such as ISO, IEC, UL, and SAE (SAE J2954, SAE J2845/6202009, IEC TS61980-2, IEC 61980-3, ISO 19363, UL 9741, SAE J2836/6_201305, and SAE J1773), was performed to understand overall recommended design parameters, e.g., dimension, frequency, and structure, and also communication protocol. These recommended parameters were further used in the electromagnetic simulation (ANSYS Maxwell) as a baseline model to explore the efficiency of magnetic coupling and the effect of various configurations on magnetic coupling between transmitters and receivers.

Finally, the LTSpice software was implemented to design the Resonant Induction Charging Circuitry for the receiver and transmitter.

Findings

A Python code was developed for marking/labeling a user-input location on an HD map; this location can be a location/coordinate of a wireless charging station. Also, a flowchart was proposed to make vector maps for navigation in the Apollo environment. Additionally, ANSYS was used to model the magnetic coupling of several designs to select the best coil configuration with the highest magnetic coupling coefficient. The design parameters, such as gap, frequency, and transmitter/receiver coils' structure, were taken from SAE J2954 as the baseline model. The magnetic coupling coefficient was used to represent the power transfer efficiency. The simulation shows that a long transmitter coil with three receiver coils provides the highest magnetic coupling coefficient. Also, ISO 15118 is recommended as the

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communication protocol between EVs and charging stations. Finally, A transmitter and receiver circuitry was proposed and simulated with LTSpices. The proposed circuitry converts a 120V AC with a frequency of 60 Hz to a 350 V DC on the receiver sides, which can be used to charge EV batteries. Figure 1 is a schematic which encompasses our findings.

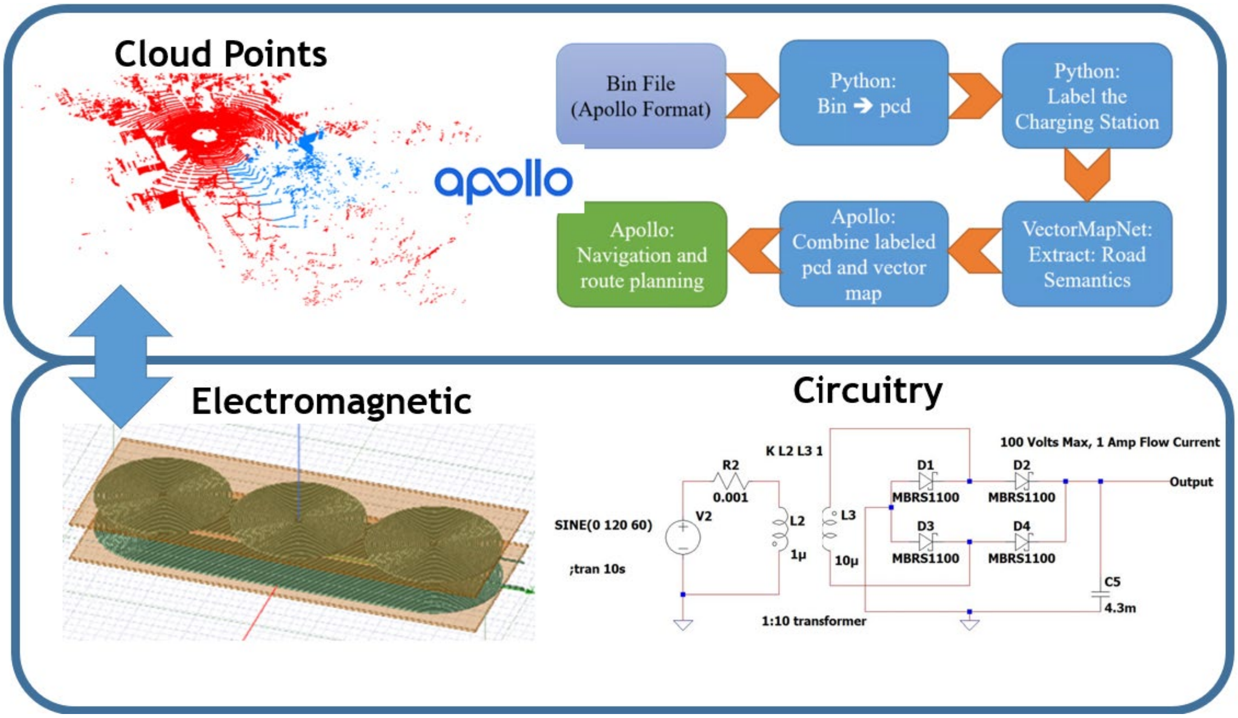

Figure 1. *Various necessary components of the wireless charging of autonomous vehicles.*

Recommendations

In the next stage, one can implement the proposed steps with open-source software such as Apollo and Vector Map Net to automatically label the wireless charging stations and simulate the EV's navigation toward the station. This implementation can serve as a proof of concept of our approach.

Also, plans for the circuit could be updating the overall feedback loop of the circuit to use smaller capacitors; currently, the capacitors used in simulation with the rest of the circuit would be hard to purchase, so with the use of some clever circuity such as putting more capacitors in parallel one can lower the individual capacitors capacitance while increasing the number of capacitors. We also recommend creating a small-scale model system to check the validity of circuit and electromagnetic designs in the future. If one can validate the accuracy of these simulations, then they can be used to explore the design space and optimization of circuitry and electromagnetic efficiency. Finally, a more detailed analysis of the communication protocol between EVs and charging stations is necessary.

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