Improving the MAD Max

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***Abstract*—Electric bikes are becoming an increasingly attractive solution for transporting goods between short distances, especially in city-wide infrastructures. However, most commercially available controllers rely on complex integrated circuits making repair and local manufacturing difficult, particularly for organisations operating in resource-constrained or low-tech environments. La Manufacture Autonome Décentralisée (LaMAD) is developing products and solutions, particularly e-bikes, which are more repairable and sustainable. Previous studies have predominantly focused on performance optimisation of Field Oriented Control (FOC) and trapezoidal commutation strategies, with limited attention to repairability, component sourcing, and community-centred sustainability criteria. This project aims to design, assemble, and develop a functional, low-tech and open-source motor controller for electric cargo bikes. The current model uses an open-source motor control called VESC (Vedder Electronic Speed Controller) that allows precise control of electric motors. The controller needs to be compatible with a VESC controller and easily locally repairable by LaMAD. By exploring the inner workings of the VESC project, modelling of the physical systems and the Printed Circuit Board, PCB, we investigated the ways we could do it in another way. We acquired a VESC controller to compare our system and a commercial product. Preliminary results demonstrate that the adapted VESC-based controller successfully drives the target motor under both commutation strategies, and that positional control is achievable with the current hardware configuration. Security vulnerabilities related to open Bluetooth access were identified. These findings suggest that open-source, locally fabricated motor controllers can meet the functional requirements of electric cargo bikes while significantly improving repairability.**

***Index Terms*—VESC Project, Brushless DC motor, Field Oriented Control, Trapezoidal commutation, Low-Tech, e-bike.**

I. Introduction

The fast urbanization of global logistics has positioned electric cargo bikes as a primary solution. At the heart of these vehicles is the motor controller. Current research and industry standards primarily focus on two methods of commutation for the controller: Trapezoidal commutation and Field Oriented Control (FOC).

As motor controllers become smarter, they increasingly incorporate wireless connectivity for tuning and diagnostics. Current research highlights that while Bluetooth Low Energy (BLE) and mobile app integration improve user experience, they often introduce vulnerabilities. Open-source projects, in particular, must balance ease of access for community developers with the need to secure the vehicle.

We also argue the need for general public's safety when it comes to these bikes, as it could be a danger to the traffic. This is especially true when it comes to vehicules carrying a substantial load. This needs to be considered by laMAD, where their responsibility and control begins and ends. Should there be a difference between the firmware loaded on a product from laMAD than what is publicly available?

II. Litterature review

III. Research gap

Despite this progress, limited research has examined the adaptation of open-source motor controllers to LowTech and repairability constraints. To date, researchers have not addressed the challenge of designing a controller that can be locally fabricated, repaired with standard components, and secured against unauthorised wireless access requirements that are critical for decentralised, community-operated fleets.

IV. The aim of the study

This report presents the design and implementation of a VESC-based motor controller tailored to the needs of the Manufacture Autonome Décentralisée (MAD), an organisation operating electric cargo bikes and freight tricycles. We aim to

focus on adapting the VESC open-source firmware to support both FOC and trapezoidal commutation, integrating positional control, and addressing Bluetooth security, while prioritising local manufacturability at INSA Toulouse.

V. Software and Connectivity

A. BLE Compatibility With the VESC

VESC-controllers are not necessarily equipped with Bluetooth-modules by default. Often, it is necessary to add a BLE-module. A standard HC-05 bluetooth-module compatible with arduino is a great way to send and recieve bluetooth-packets from a host, e.g. a mobile phone, via a bridge translating the bluetooth packets to the UART protocol. This is because the HC-05 is not adapted for BLE as a base. Needing a bridge also adds on complexity and cost, in the form of extra components and another device to maintain the code of. For the future, choosing a bluetooth module supporting BLE will be the easiest solution.

B. BLE Vulnerability

Bluetooth could be a vulnerability to a VESC if it is to be used as a controller in real-time, as the controller could be jammed. Our test with the Flipper Zero shows the disfunctionnality of Bluetooth with different use cases. It could also be investigated how the connection to the VESC could be modified using the vesc tool. We will touch more on the accessability of the code within the vesc tool sooner.

C. Testing of BLE-modules

What we have done: Flash VESC on a discovery-card. We connected the HC-05 module to the PB10 and PB11-pins, which are the Rx and Tx-pins for the STM32F4xx chip. We discovered that the setup for the bluetooth module was not available in the VESC tool. The inherent BLE capabilities is an important limitation to consider when designing a VESC system.

VI. Code integrity

As the project is open source, and the code is freely accessible, there should be no reason to hide the code. It could however be reasonable to protect the code from changes which could hurt other people. Changing following parameters should at least come with a disclaimer and clearly state the dangers possible by proceeding with said changes. We have in mind the maximum speed permitted and the power available to the motors.

A. VESC compiling

We have been able to compile the VESC tool and the VESC firmware. This firmware has been put onto an STM32F4xx Discovery card. This poses several obstacles for our progress on the topic of cybersecurity. We will however summarise what we have learned for you and propose some additional work for the future. The challenges we encountered were the following: The lack of bluetooth capabilities. We did not have a module with BLE eiter. We had access to a HC-05 module, but that only allows for a normal bluetooth protocol and would require further work on a bridge to UART by using an esp8622 that we had as well. We propose that the next group has access to a VESC controller from the beginning, as well as a motor we could control. This could be in cooperation with laMAD, as laMAD could propose some models they're interested in.

We also found that the information on the VESC is scattered around the net. The ressources is also sometimes based on a debian-based linux system which adds more work for someone using another distribution of linux. This could hinder the implementation facility for new users. We struggeled particularly with the Qt packages for positioning and gamepad. We would therefore recommend the use of a debian-based linux system for the computer working with the VESC for the laMAD associates.

B. lispBM extraction

We caugth word that the lisp code for the VESC used by Maillon mobility was easy to extract. By building an older firmware with the Maillon mobility software, we observed this by going to the lispBM tab and clicking read. It's up to laMAD if they would like to reinforce this mechanism. A modification on a parameter and then clicking upload allowed us to easily change the speed limit. This could bring up a public danger. This raises questions on the use of laMADs equipment which is in a traffic friendly manner.

When we flashed newer firmware from the project made by Benjamin Veeder[1], we also observed some difficulties in uploading the lispBM script taken from the one on firmware version 6.06. This could indicate that there needs to be further maintenance of the code in order to get the software up to speed. This needs to be documented better for someone to continue the project. This could be a good investment for laMAD as well in the context of training for the people working on the motor control part of the e-bike.

C. Discussion

This project could be seen as an introduction to the VESC project for someone who don't know about it from beforehand, the challenges the new users face during setup, as well as a demand for clear expectations concerning documentation on the subject. The project laMAD is leading should probably not be a fork of the project, as the project is still in development.

Acknowledgment

The preferred spelling of the word "acknowledgment" in America is without an "e" after the "g". Avoid the stilted expression "one of us (R. B. G.) thanks ...". Instead, try "R. B. G. thanks...". Put sponsor acknowledgments in the unnumbered footnote on the first page.

References

[1] M. Young, The Technical Writer's Handbook. Mill Valley, CA: University Science, 1989.

[1] https://github.com/vedderb/bldc/