**ENGR7019 Engineering Dissertation Project Proposal**

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AI-Driven Physics Based Battery Model Parameterisation with PSO-LM

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# Background

The advanced battery technology market is growing at a significant rate () and producing new ground-breaking cell chemistries. However, the technology which monitors the functional safety and performance of the battery pack in automotive and motorsport applications is still primitive and does not unlock the full potential of the new battery packs topologies.

This component is called a Battery Management System (BMS), which makes approximations for the State Of Charge (SOC) and measures other electrical conditions to decide whether the battery pack is damaged or is exceeding performance limits.

The foremost issue is not primarily a hardware-based problem, the key issue is how the battery is modelled in the BMS and the systematic approach of how the battery pack is being parameterised. Most BMS’s use Equivalent Circuit Models (ECM’s) to project SOC and functional safety breaches, but ECM’s use simulated electrical components to map the behaviour of cell. This level of modelling does not consider the physical and chemical interactions happening inside the cell, which misses the true response characteristics of the cell and takes significant testing time to obtain.

The modelling approaches this paper analyses and will look to build upon, uses physical and chemical based assumptions to better measure cell performance. However, this does come at a cost of high computational effort to analyse the complex interactions, so the dependency on data-driven Artificial Intelligence (AI) is critical.

This form of research is completely new field, so any step which requires less computational effort or time to get high fitting data is highly advantageous to the industry.

# Literature review (~1800 words and no less than 1500 words)

## ECM compared to P2D

Dd

## Sensitivity Analysis

## AI Based Optimisations

### PSO LM Optimisation

# Aim and SMART objectives

The main aim of the study is to see what physical based parameters can be optimised to predict cell behaviour via a PSO-LM method. Following are the SMART objectives:

1. Identify the primary use cases and limitations for ECM and P2D modelling.
2. Review the different sensitivity analysis parameters objectified in previous research.
3. Access different open-source battery modelling programmes and discuss the limitations and ease of use of each package.
4. Review the different AI and statistical based approaches for physical based modelling, to decide what solver would be suitable for the authors level of proficiency
5. Determine which physical based parameters should be parameterised to obtain motorsport focused performance or automotive focused performance.
6. Perform AI based modelling to understand the correlation and validate the physical cell’s measurements to simulated behaviours.

# Project methodology (~850 words)

The overall project methodology is presented in Figure 1, where it highlights where the objectives overlap with the project in different colours. Boxes with a light-yellow shade indicate literature review tasks, light blue is accessing software tools and light red is the modelling phase.

Diagram, schematic

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Figure : Overall Project Methodology

## Objective 1

Primarily this objective will be a literature review for ECM and P2D models, how they can be deployed on BMS’s, and comparing the performance advantages of P2D model with the disadvantages of hardware integration.

In addition, this section intends to look at what cell’s performance characteristics are desired for both motorsport and automotive applications, in which the research into cell tab plating, concentration of electrolyte and electrode material will be discussed

## Objective 2

This objective will again be a literature oriented, where multiple different sensitivity analysis’s will be reviewed and compared. In the expectation, that other variables to measure sensitivity can be understood and replicated for Objective 5 to give what variables should be optimised for a motorsport or automotive application.

## Objective 3

This objective will both be literature oriented and software focused, where the author will access European databases, open-source packages such as PyBAMM and report the benefits and withdrawals of operating in the software package/database. This will help inform the author what physical based packages will be carried over to the entire model development.

## Objective 4

This objective will be literature based, where different previous research for AI and statistical based models for P2D optimisations will be analysed. In the expectation, that this identifies what gaps there are in the field of AI based P2D models and how the project could capitalize on methods such as PSO-LM.

## Objective 5

This objective is software based, where the initial groundwork for the model begins. As the author will experiment in replicating previous sensitivity analysis for conditions such as cell temperature change effect to terminal voltage. With the expectation, that it will be integrated into a software platform that can handle the demands of an AI solver.

## Objective 6

The last objective is software driven, where the model is in its development and validation phase. This will use the work from Objective 5 and combine it to the backend code for the AI based optimisation tool, furthermore this will utilise real life data generated from a full life characterisation of a LG M50 cell to help develop the model and train the AI to yield closer fitting simulations for cell behaviour. At this stage, if the model is unsuccessful the author can formatively review the short comings of the model and approach.

## List of Alternatives (in tabular form)

### List of limitations (in tabular form)

# Activities and time plan (no wordcount as it is in a tabular form)

* List the activities and allocate appropriate time to carry out them. **Use tabular format for this. The words in the table are not considered in the wordcount.**
* **Activities relate to methodology and objectives**.
* Aim to have at least 10 major activities and then split the activities into sub-activities if appropriate.
* Use Gantt chart to show the full plan, showing project deliverables clearly.
* The university has access to Microsoft Project, hence the students are advised to make full use of it in their project planning.
* Please enhance the Gantt chart by identifying the critical path.
* The Gantt charts so created often require larger page sizes but for printing and ease of use reduce them to a single A4 page.
* The presentation is important; all text should be easily readable. The choice of bar patterns should make the critical path clear to see.

# Resources

This project is in collaboration with HVES, which will be using a complete data set of the LG M50 Cell, to help develop and train the AI physical based model.

The project intends on using the following software packages and tools:

* PyBAMM – Python package for battery
* Chen2020 dataset from PyBAMM for provisional sensitivity analysis
* Julia
* GitHub – open access repository for code and documentation

# 

# Project risks

Table 1: Risk analysis of tasks

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Task at Risk** | | **Resource at Risk** | **Objective(s) at Risk** | **Description** | **Consequence** | **Magnitude (/5)** | **Control** | **Likelihood (/5)** | **Contingency** | **Risk Factor**  **(M x L, /25)** |
| R1 | Unable to get to grips with AI based software | Model | 6 | The software package does not have enough learning material to understand how to use it | Unable to develop a cohesive AI based Model | 5 | Select packages which are very familiar to the Author | 3 | If unable to produce an AI focused model, make it is a purely statistical based model. | 15 |
| R2 | Code gets corrupted, overwritten or lost | Model | 3,5,6 | The backend code for the overall model gets corrupted, overwritten or lost | An incomplete model | 4 | Use a repository like GitHub to store code and commit versions of code | 1 | Back up the repository on separate hard drive | 4 |
| R3 | The model does not perform closely to previous literature | Model | 6 | The model does not provide a good fit to the physical testing data | A model which is not conceived as successful | 4 | Make every attempt to make the best model the author can produce in the timeframe for the thesis | 3 | If unsuccessful, make a formative review on how the approaches taken are flawed as that will definitely inform industry on the suitable models to deploy | 12 |
| R4 | Unable to decide between a motorsport or automotive focused optimisation | Literature and model | 1,5 | The literature is too vast to determine how the P2D should be targeted to optimise motorsport performance or automotive functional safety | The model may have too much scope and does not fit data well enough | 2 | Develop the two perceptions in tandem, but understand when the scope has exceeded plausibility | 3 | If in doubt, use an automotive focused approach. As there is much more work in automotive focused models, therefore grounds the topic more firmly | 6 |
| R5 | Unable to get sufficient computational power | Model | 6 | The model takes far too long to run on personal PC | The validation phase may exceed the timeline | 3 | Ensure code is computationally efficient to MISRA C | 1 | Rent cloud computing space and run API’s | 3 |

## Risk Matrix

It is critical to ensure that risk management is incorprated into the project plan, to quantify the problems and measure the probabilty of failure for particular tasks. Therefore, the risks mentioned in have been transposed onto the following risk matrix (Table 2). Where the product of the combined scores for likelihood and magnitude forecasts the possible failure probability.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 5 |  |  |  |  |  |
| 4 |  |  |  |  |  |
| 3 | R5 | R4 |  | R3 | R1 |
| 2 |  |  |  |  |  |
| 1 |  |  |  | R2 |  |
| /5 | 1 | 2 | 3 | 4 | 5 |

Table 2: Risk Matrix

**Magnitude**

**Likelihood**

# References (not included in word count)

List the key Journal articles and books relevant to the project. You are expected to use a minimum of 10 relevant, good, journal articles. Further to that you can also use books.

Use Harvard style of referencing – please refer to library website for more information.

**The word count given out for each section is indicative; you can use +10% words in any section but the total for all seven sections together should be ≤ 3000 words.**