PyBaMM

Python Battery Mathematical Modelling

UNIVERSITY OF OXFORD · Carnegie Mellon University · UCL · Imperial College London · WMG THE UNIVERSITY OF WARWICK · THE FARADAY INSTITUTION · MultiScale Modelling

The PyBaMM Team

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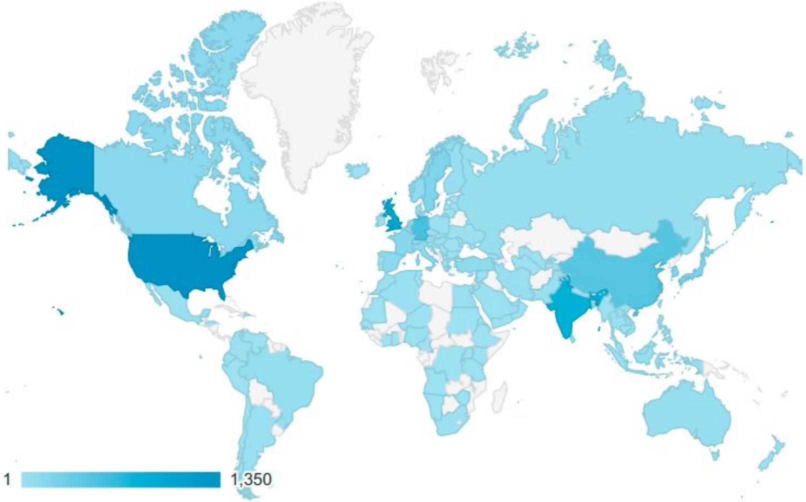
Python Battery Mathematical Modelling

*PyBaMM's mission is to **accelerate battery modelling research** by providing an **open-source framework** for multi-institutional, interdisciplinary **collaboration**.*

- **Provide fast, reliable battery simulations**
- **Grow battery modelling community**
- **Facilitate development of new battery models**
- **Improve reproducibility of research**
- **Increase impact and industry engagement**



*PyBaMM has fostered an active community with almost **40 contributors** and **hundreds of users**. Our most recent training workshop attracted almost **400 participants**, **over 100** of which were from **industry**.*

Try online

Install locally

GitHub

Develop

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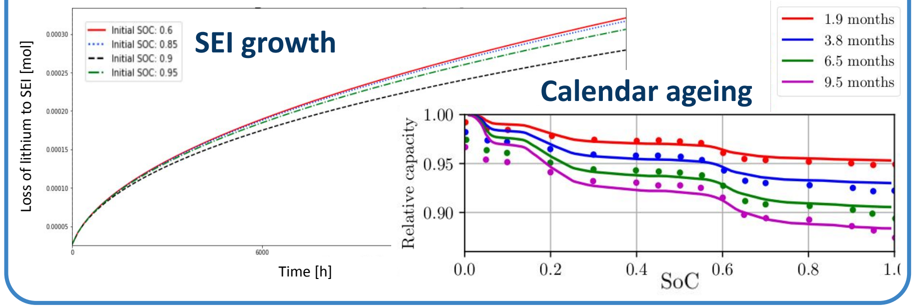
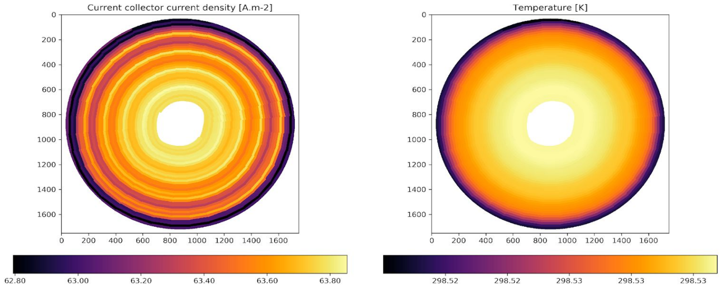
Python Battery Mathematical Modelling

A design tool for predicting behaviour, a virtual physics lab to explore new mechanisms, a quality control environment to compare models, and a testing ground to validate model predictions.

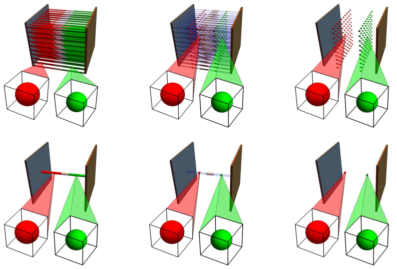
INCORPORATE "PLUG AND PLAY" PHYSICS

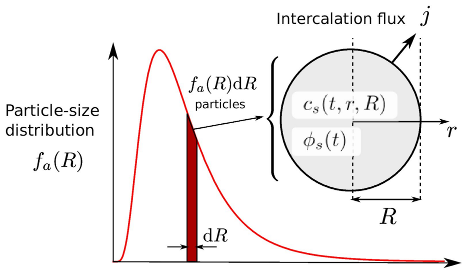


INVESTIGATE CELL DESIGN

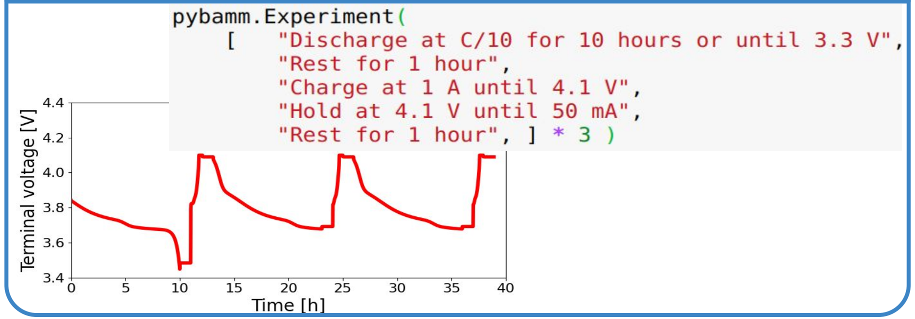


COMPARE MODELS FOR ACCURACY AND SPEED





SIMULATE EXPERIMENTAL PROTOCOLS



```
pybamm.Experiment(
    [    "Discharge at C/10 for 10 hours or until 3.3 V",
         "Rest for 1 hour",
         "Charge at 1 A until 4.1 V",
         "Hold at 4.1 V until 50 mA",
         "Rest for 1 hour", ] * 3 )
```

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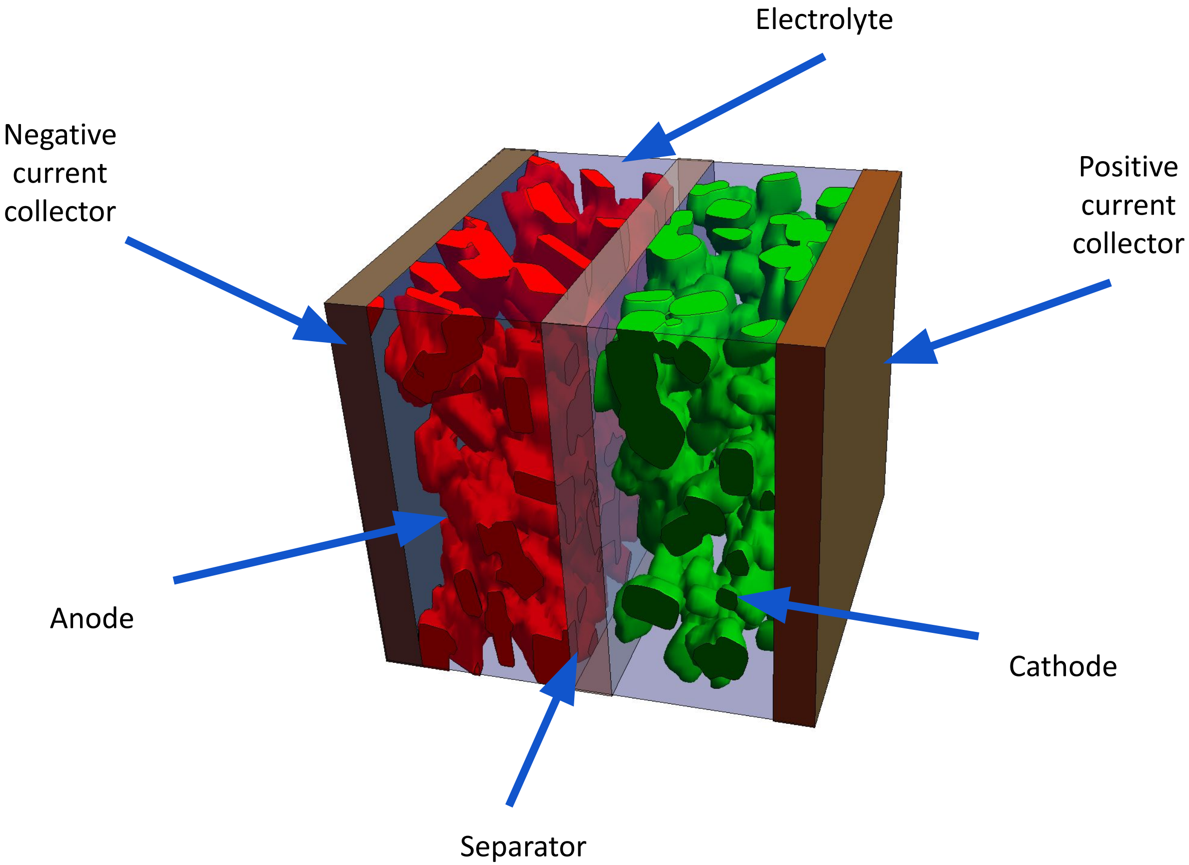
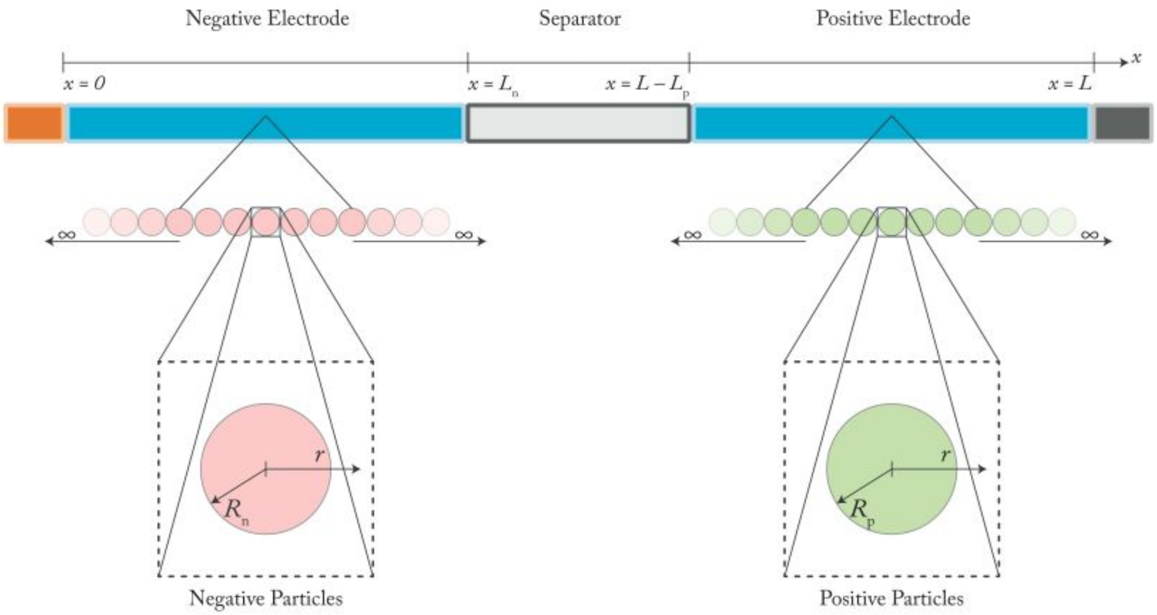
What is a physics-based model?



What is a physics-based model?



“Doyle-Fuller-Newman model” or “Newman model” or “Pseudo two-dimensional model”

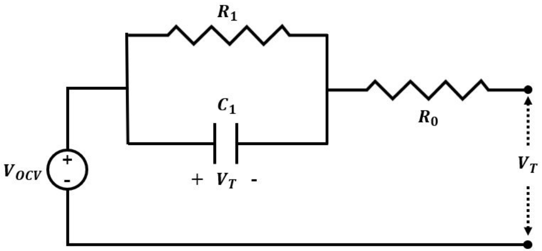
Why physics-based models?

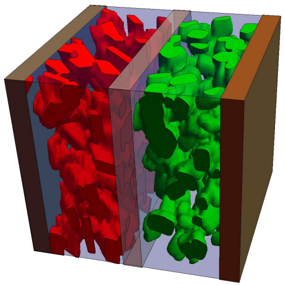
Computational cost

Equivalent Circuit Models (ECMs)

- ✓ Computationally cheap
- ✓ Simple
- ✓ Not many parameters

- × Limited physical insight
- × No internal dynamics
- × Only good for interpolating





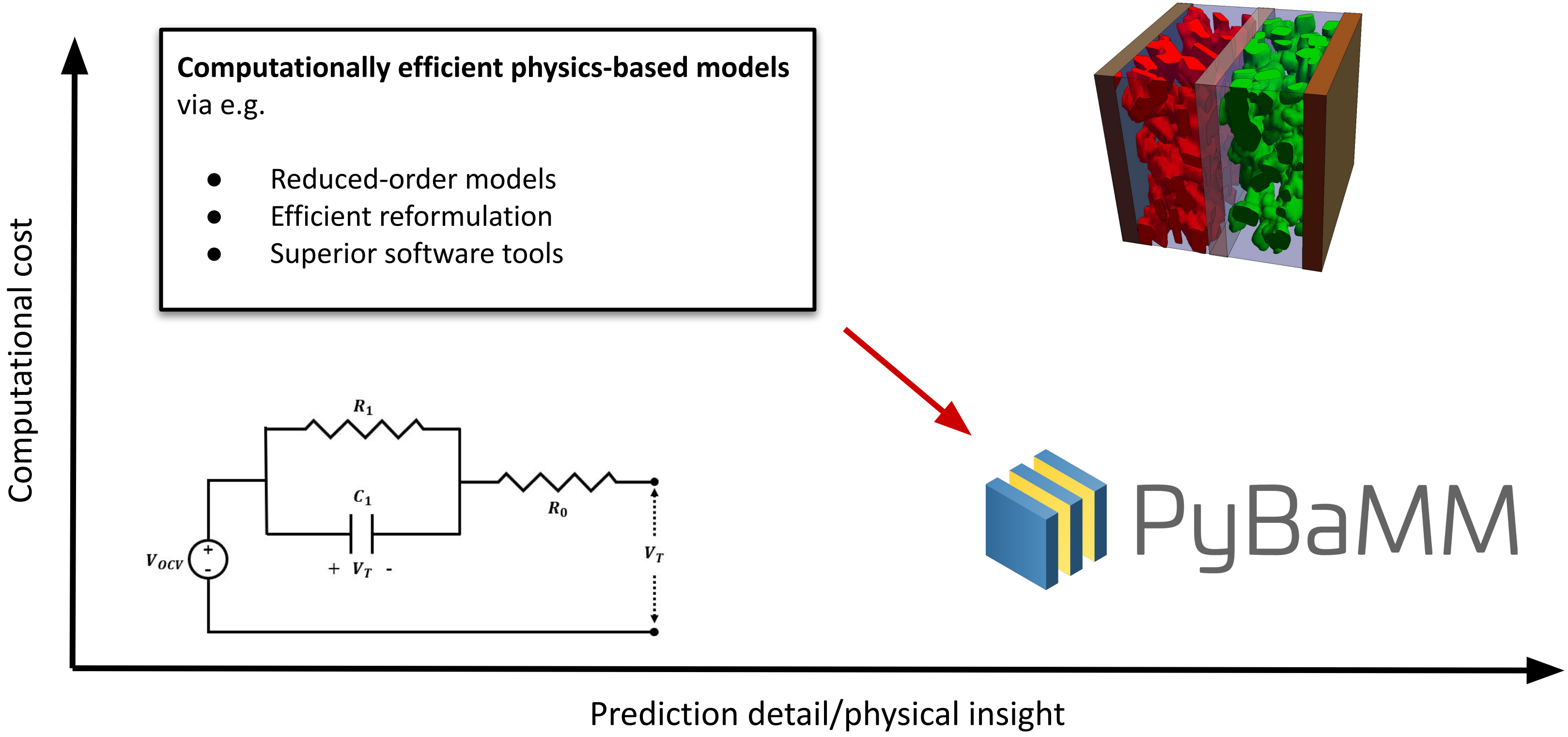
Traditional physics-based (PDEs)

- ✓ Gain insight
- ✓ Predict internal dynamics
- ✓ Wide range of validity

- × Lots of parameters
- × Computationally expensive
- × Comparatively difficult to formulate

Prediction detail/physical insight

Why physics-based models?



Computationally efficient physics-based models via e.g.

- Reduced-order models
- Efficient reformulation
- Superior software tools

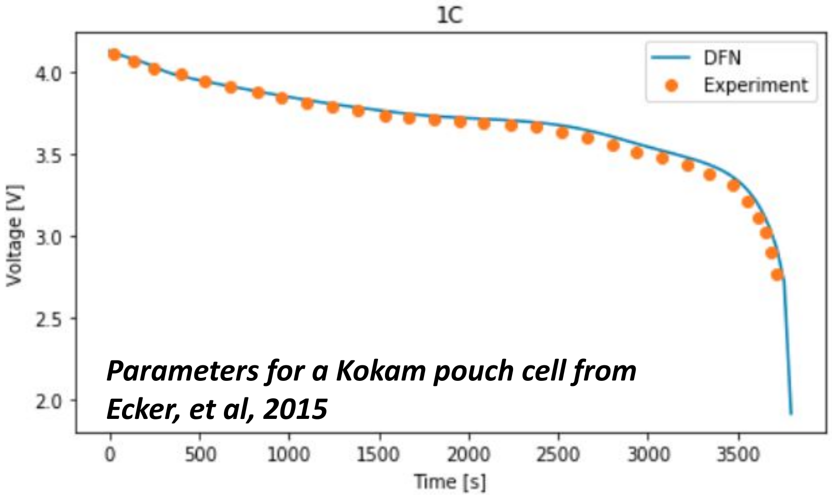
Computational cost

Prediction detail/physical insight

Fast, reliable simulations via a simple interface

PyBaMM's user friendly interface makes simulating battery behaviour easy

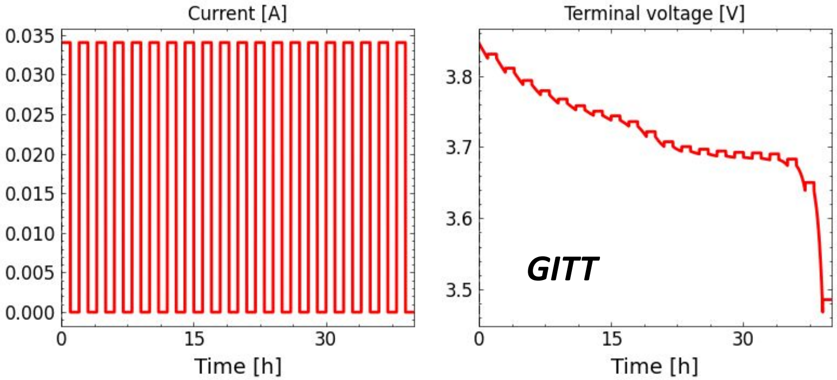
TEST & VALIDATE MODELS & PARAMETERISATIONS



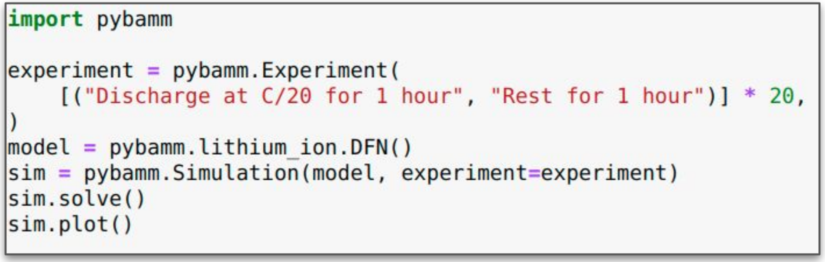
Parameters for a Kokam pouch cell from Ecker, et al, 2015

1 hour discharge of the ***DFN*** *model with* ***over 20, 000 states*** *solves in less than* ***3s*** *on a standard laptop. With* ***300 states*** *the solve time is just* ***35ms****.*

EASILY DEFINE EXPERIMENTAL PROTOCOLS OR PROVIDE DRIVE CYCLE DATA



GITT



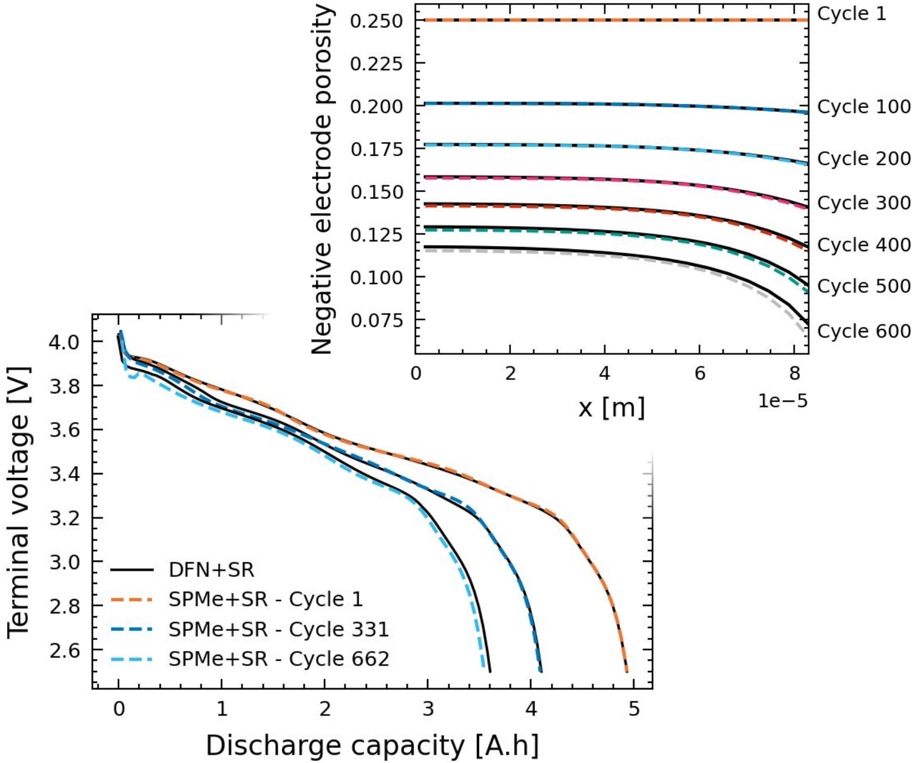
```
import pybamm

experiment = pybamm.Experiment(
    [("Discharge at C/20 for 1 hour", "Rest for 1 hour")] * 20,
)
model = pybamm.lithium_ion.DFN()
sim = pybamm.Simulation(model, experiment=experiment)
sim.solve()
sim.plot()
```

Advanced multi-physics battery models

PyBaMM's flexible submodel structure enables true plug and play physics

- **Comprehensive** model library, including full and reduced-order models
- **Plug and play** submodels describe **key physics** and are all **fully coupled**
- Connections between submodels allow **multiple physical effects and their interactions to be understood**
- Predict cell **performance and lifetime** through coupled **electrochemical-thermal-mechanical degradation** models
- Track changes in behaviour through various **health metrics**, e.g. capacity fade, LLI, LAM

Extra options include SEI growth, lithium plating, mechanics, particle size distributions, and more!



Accessing support

PyBaMM doesn’t do something you think it should?

Not sure how to use existing features or implement your own model?

Interested in commercial or academic collaboration?

Please get in touch!

Get in touch on Slack or email

Use the #technical-questions channel, send a direct message, or send us an email

Create an issue or discussion

Head over to GitHub and post an issue or start a discussion

Implementation Sessions

One-on-one or group session to workshop your ideas, discuss implementation details and help with any issues

Accessing support

PyBaMM doesn’t do something you think it should?

liionpack

New pack modelling software in PyBaMM ecosystem currently under active development!

Visit https://github.com/pybamm-team/liionpack

send a direct message, or send us an email

start a discussion

workshop your ideas, discuss implementation details and help with any issues

New issue