EuroHPC PL

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National Supercomputing Infrastructure for **EuroHPC**

E-platform for Quantum Machine Learning

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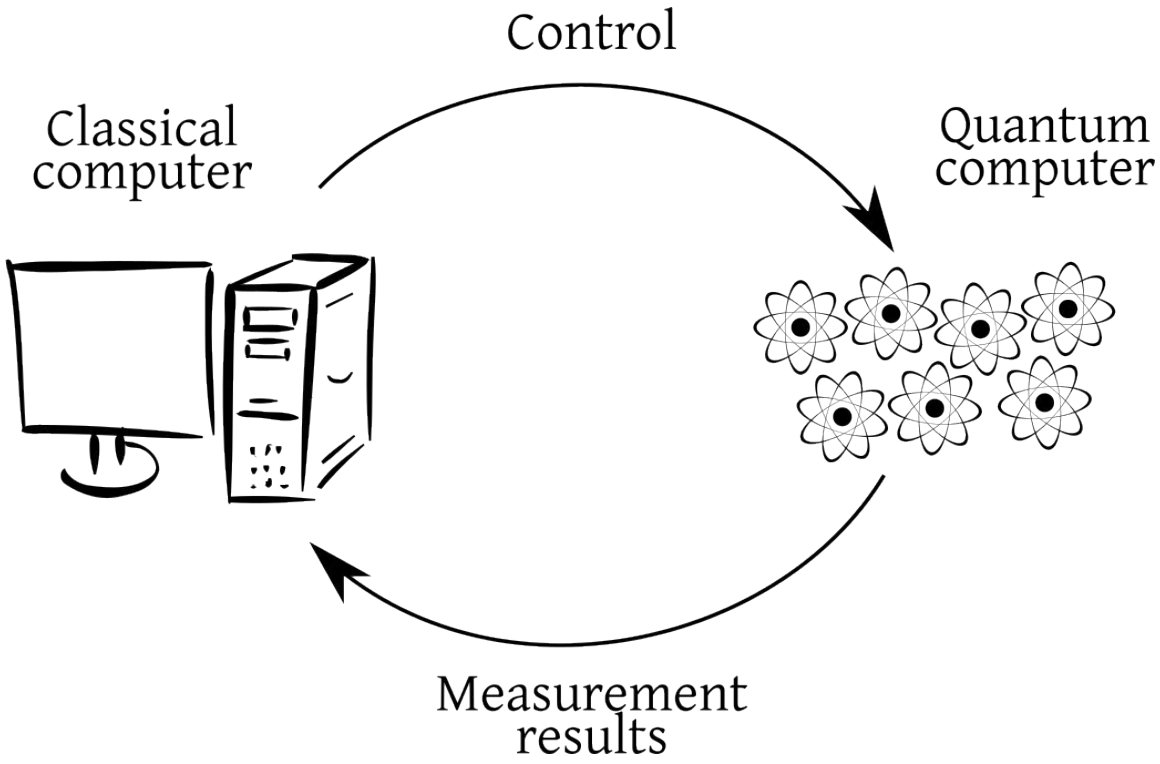
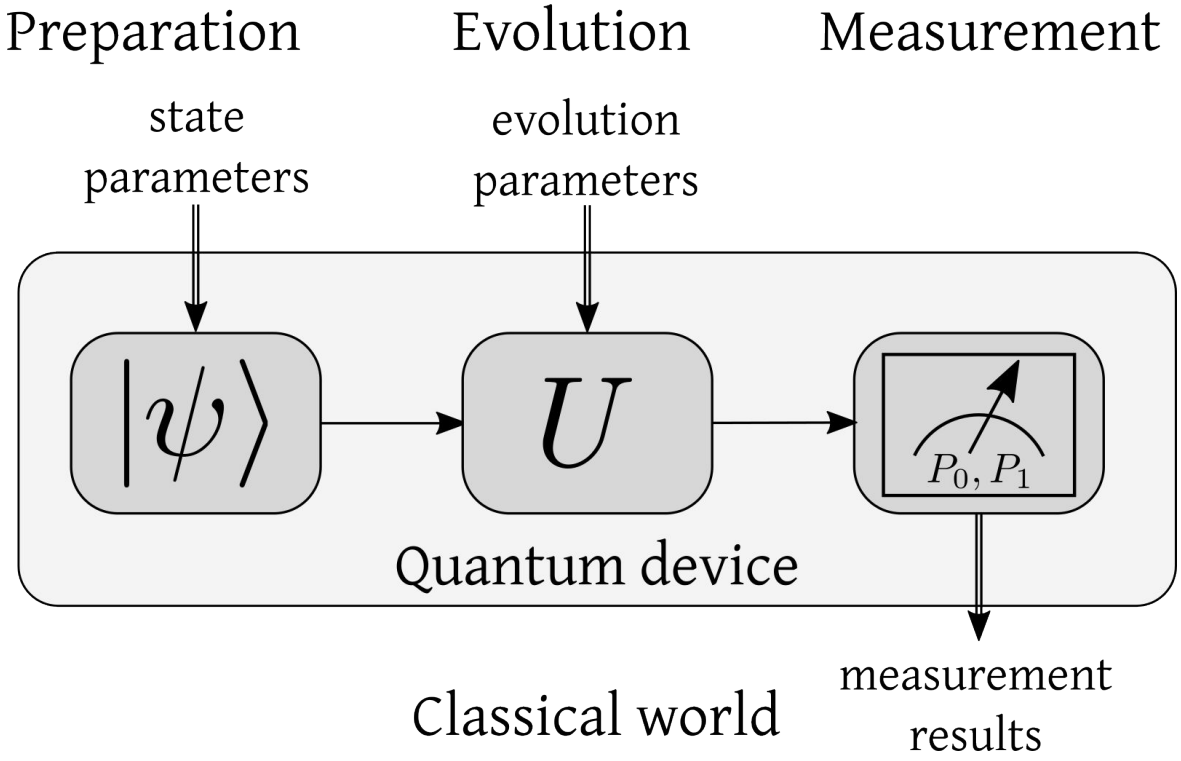
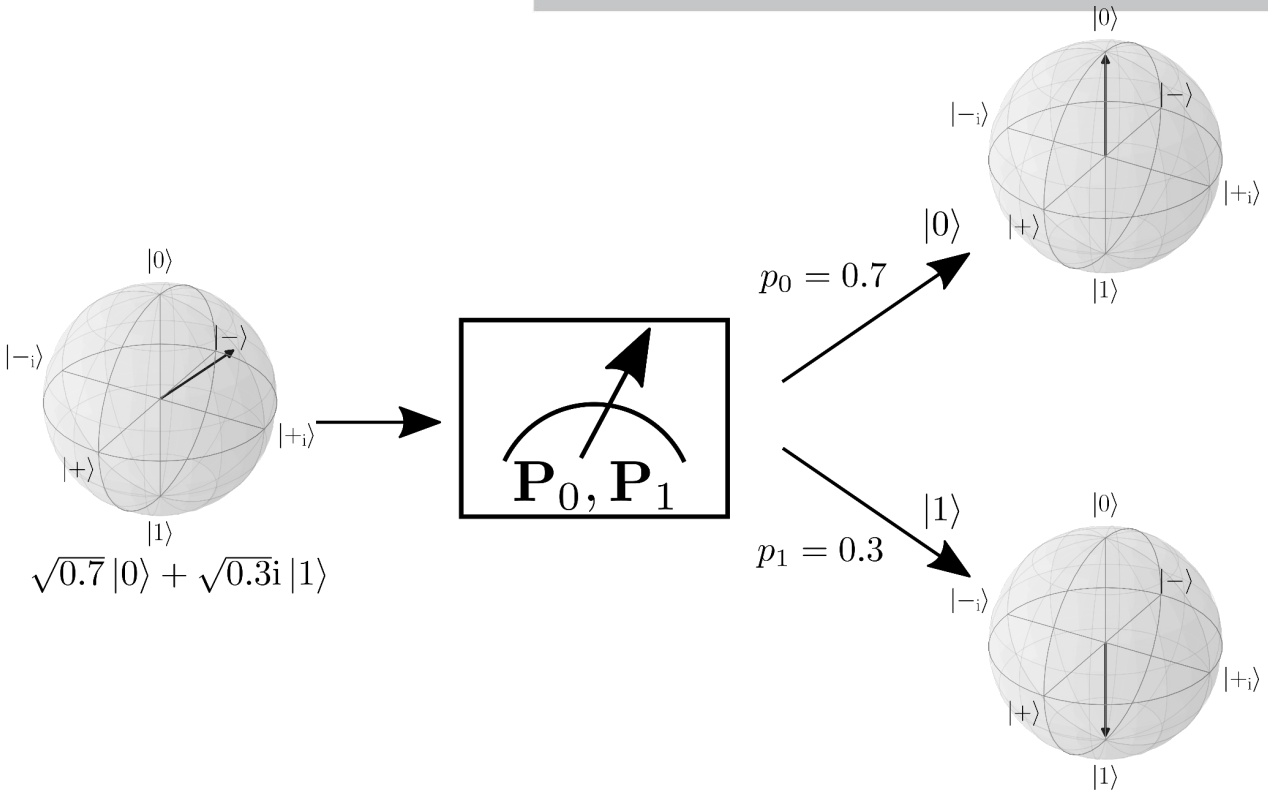
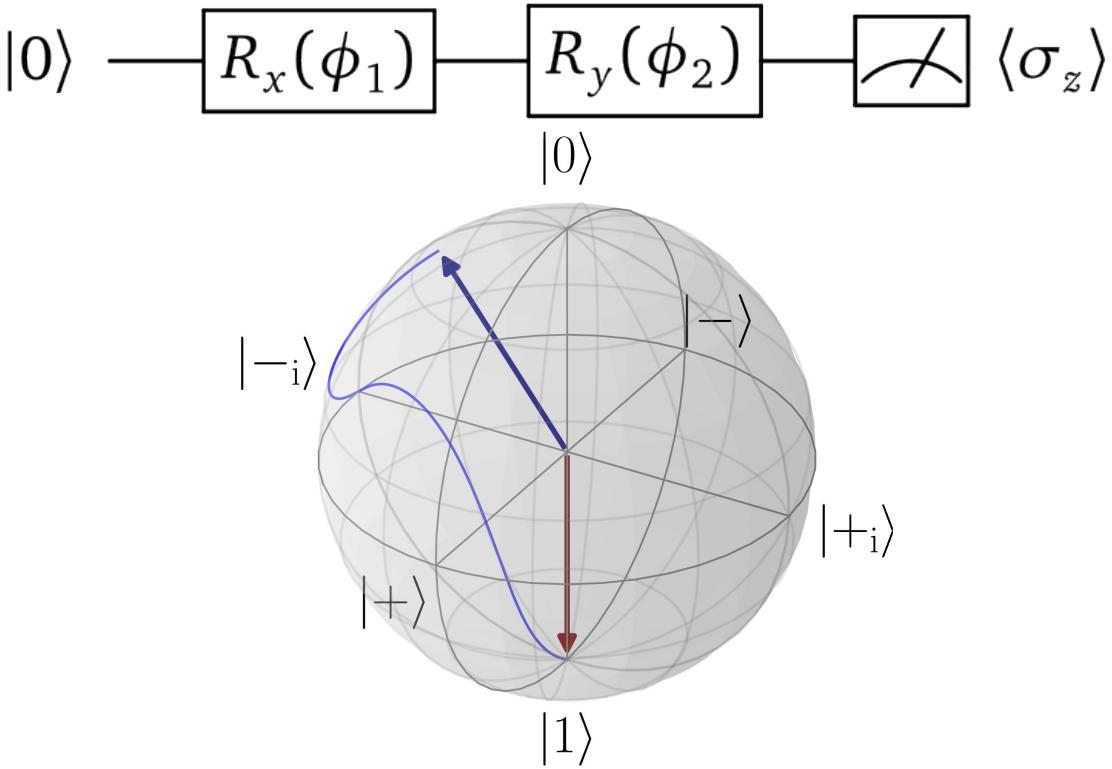
European Funds Smart Growth
Republic of Poland
European Union European Regional Development Fund

Quantum variational computing in less than 6 minutes + 2 minutes for quantum neural networks

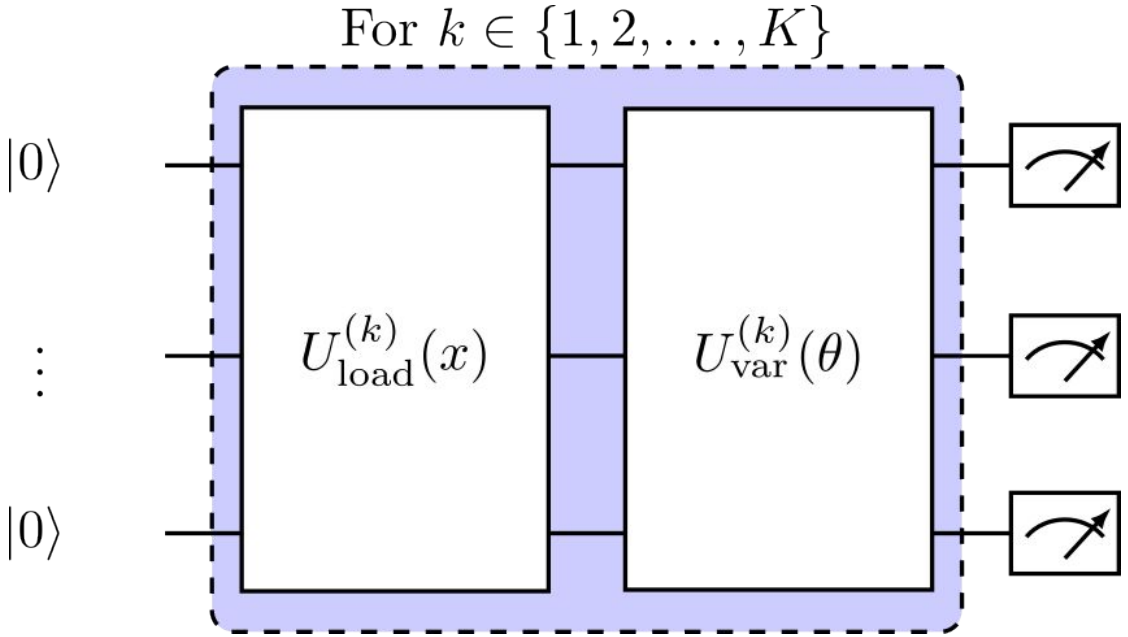

Control
Classical computer
Quantum computer
Measurement results


Preparation
Evolution
Measurement
state parameters
evolution parameters
$|\psi\rangle$
U
P_0, P_1
Quantum device
Classical world
measurement results

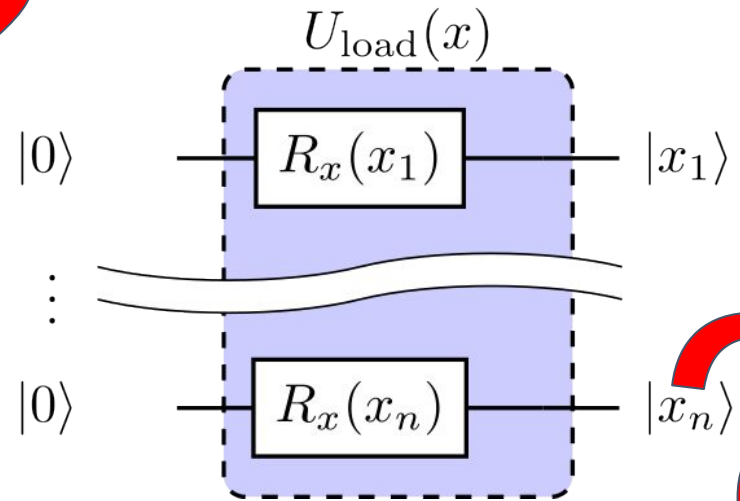

$|0\rangle$
$|-_i\rangle$
$|-\rangle$
$|+_i\rangle$
$|+\rangle$
$|1\rangle$
$\sqrt{0.7}\,|0\rangle + \sqrt{0.3}\mathrm{i}\,|1\rangle$
$\mathbf{P}_0, \mathbf{P}_1$
$p_0 = 0.7$
$|0\rangle$
$p_1 = 0.3$
$|1\rangle$

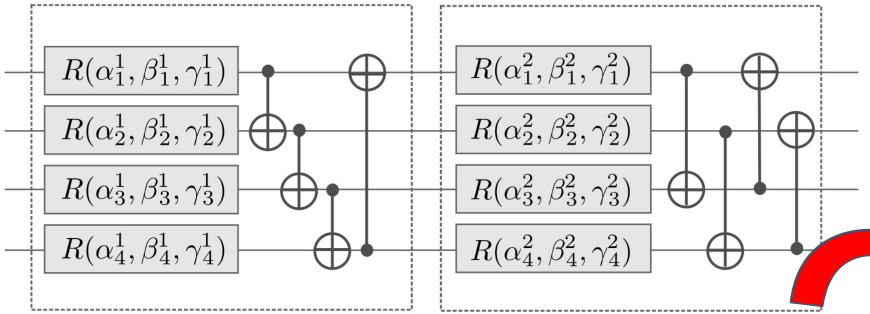

$|0\rangle$
$R_x(\phi_1)$
$R_y(\phi_2)$
$\langle\sigma_z\rangle$
$|0\rangle$
$|-\rangle$
$|-_i\rangle$
$|+_i\rangle$
$|+\rangle$
$|1\rangle$

Quantum Neural Networks



Data loading / variational Ansatz



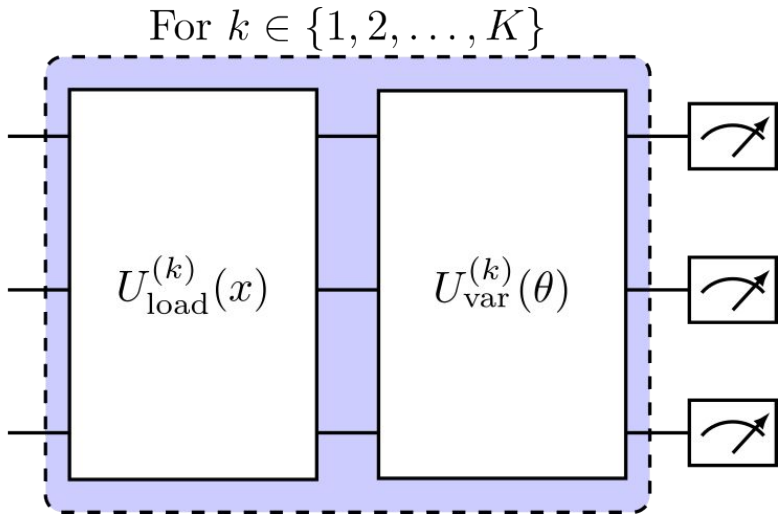


Source : https://pennylane.ai/

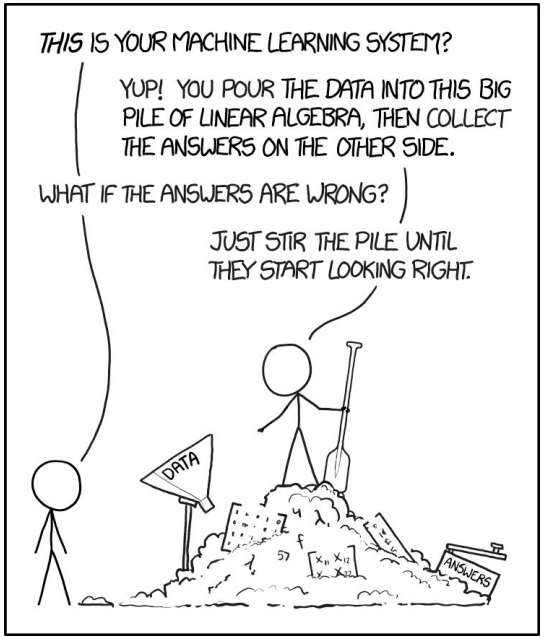
AQMLator - Auto Quantum Machine Learning e-platform

Introduction to AQMLator

- **AQMLator:** A black-box platform designed to automate the process of finding the optimal ansatz for quantum machine learning (QML) models for people without Quantum Computing knowledge.
- **Objective:** Find eficient QML models.
- **Approach:** Leveraging advanced optimization techniques, including Optuna.
- **Impact:** Simplifies the process for ML practitioners, enabling more accessible and effective quantum computing applications.



Treating Ansatz as a Hyperparameter



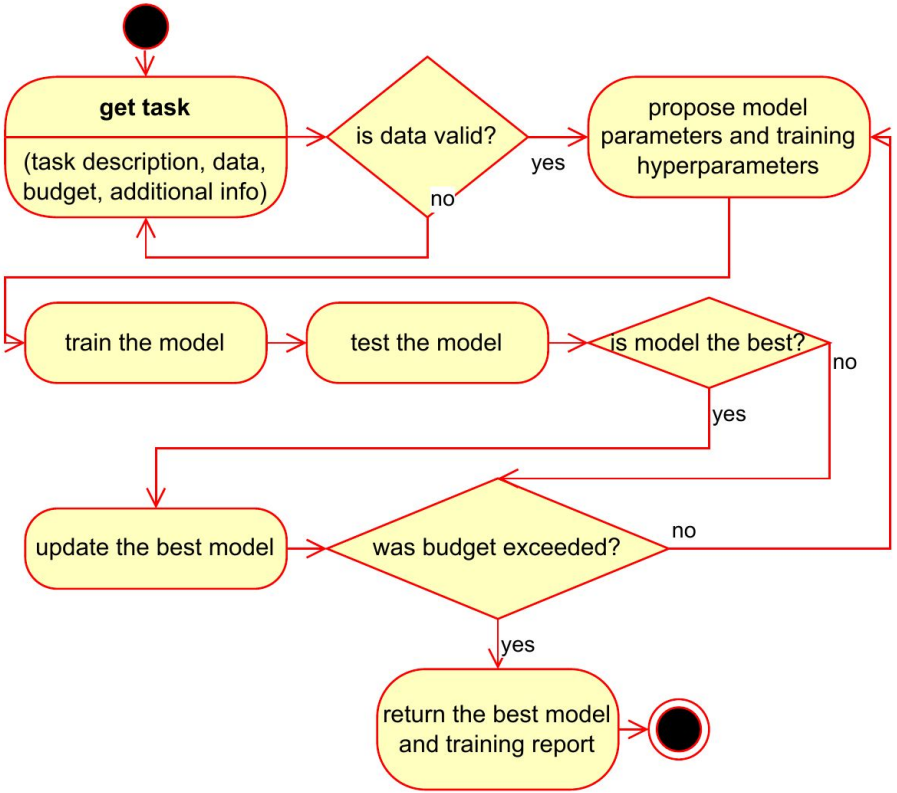
Source: Great comic strip by xkcd.
(https://xkcd.com/license.html)

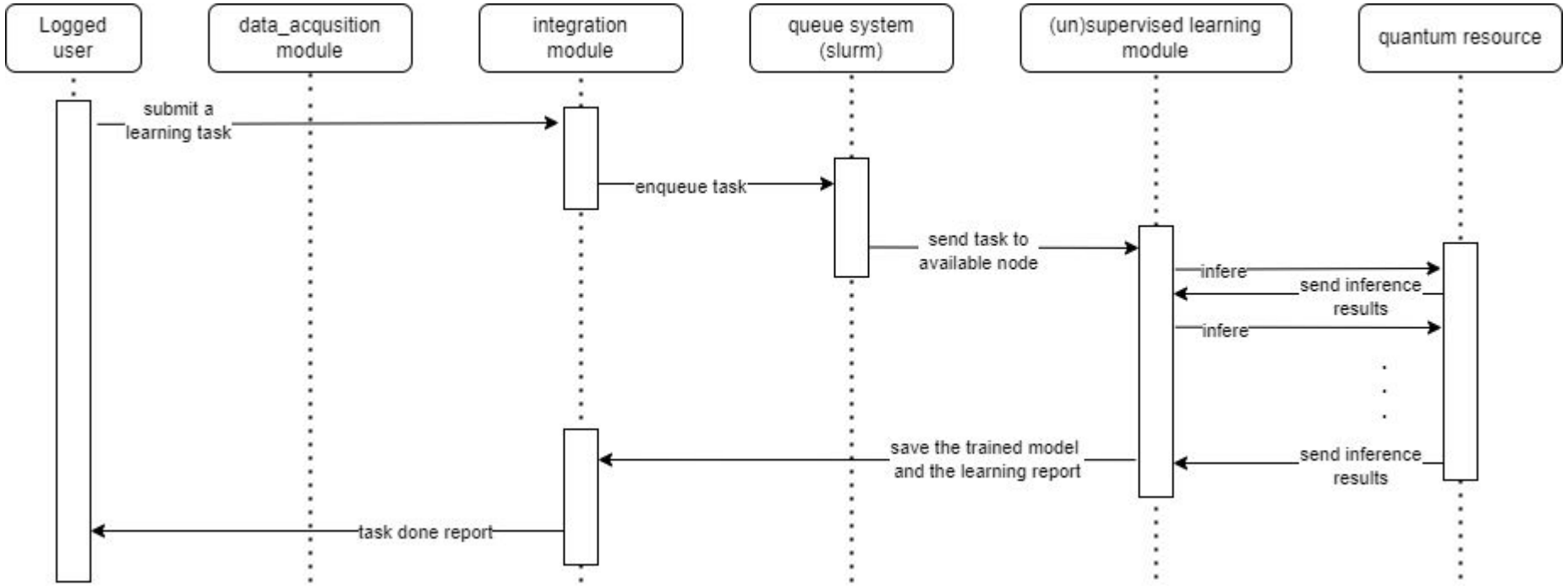
- **Low-key Ansatz Selection:** AQMLator introduces an unexplored method by considering the circuit ansatz as a hyperparameter in quantum machine learning models.
- **Optuna for Optimization:** Utilizes Optuna, a sophisticated optimization framework, to systematically explore and select the most suitable ansatz.
- **Adaptive and Dynamic:** This approach allows the platform to adapt dynamically to various QML problems, ensuring optimal model performance.
- **Enhancing Model Efficiency:** By automating the quantum model finding and expressing it as a torch (sub)model, AQMLator allows for an easy introduction of QML models into existing ML pipelines.
- **Accessible to Non-Specialists:** This innovation opens up quantum machine learning to a wider audience, including those with limited quantum computing expertise.

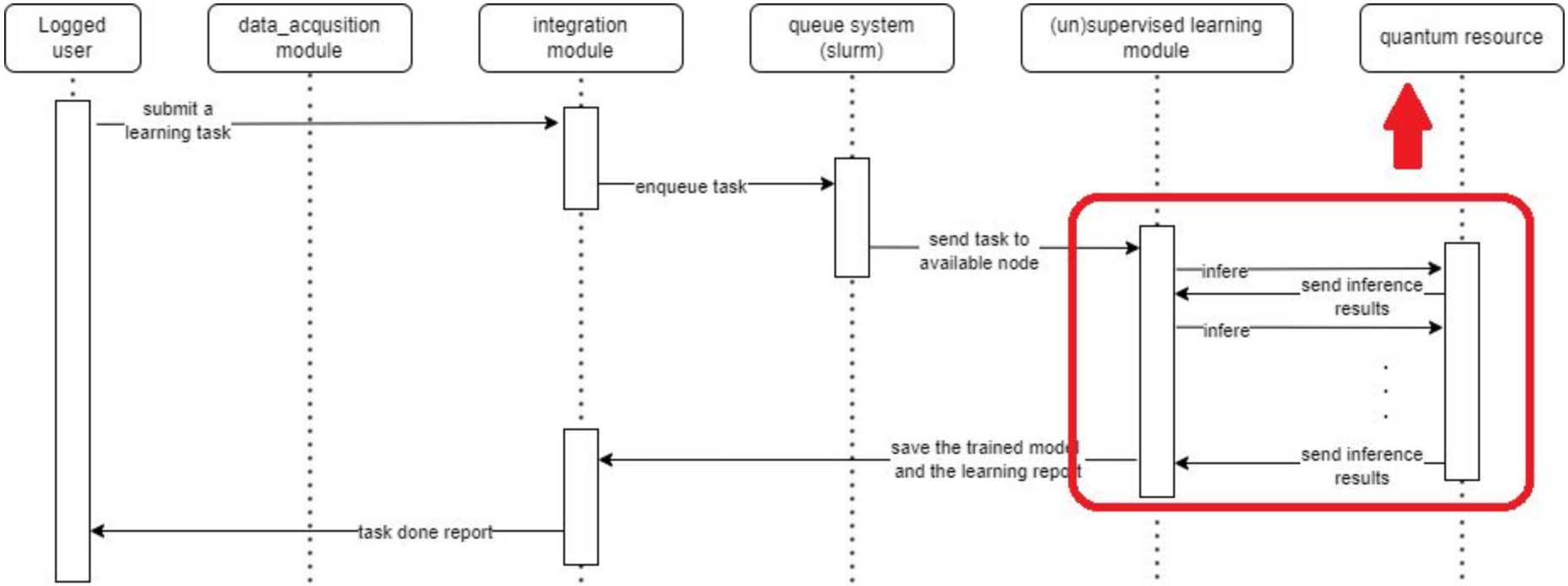
AQMLator's Core Mechanism

- **Building Blocks:** AQMLator utilizes well-founded quantum circuit layers implemented in the PennyLane library, ensuring a robust foundation for constructing quantum models.
- **Device Access:** AQMLator offers compatibility with actual quantum devices provided by IBM and D-Wave, allowing users to implement and test models on real quantum hardware.
- **Optuna Integration:** The platform employs Optuna for ansatz selection and advanced hyperparameter tuning.
- **Optuna Dashboard:** The Optuna Dashboard utility enables in-depth investigation of the ansatz discovery and hyperparameter tuning processes. This feature facilitates interesting insights and explorations, enhancing the understanding of model optimization with rich visualizations.


How does it work?


get task
(task description, data, budget, additional info)
is data valid?
no
yes
propose model parameters and training hyperparameters
train the model
test the model
is model the best?
no
yes
update the best model
was budget exceeded?
no
yes
return the best model and training report


Logged user
data_acqusition module
integration module
queue system (slurm)
(un)supervised learning module
quantum resource
submit a learning task
enqueue task
send task to available node
infere
send inference results
infere
send inference results
save the trained model and the learning report
task done report


Logged user
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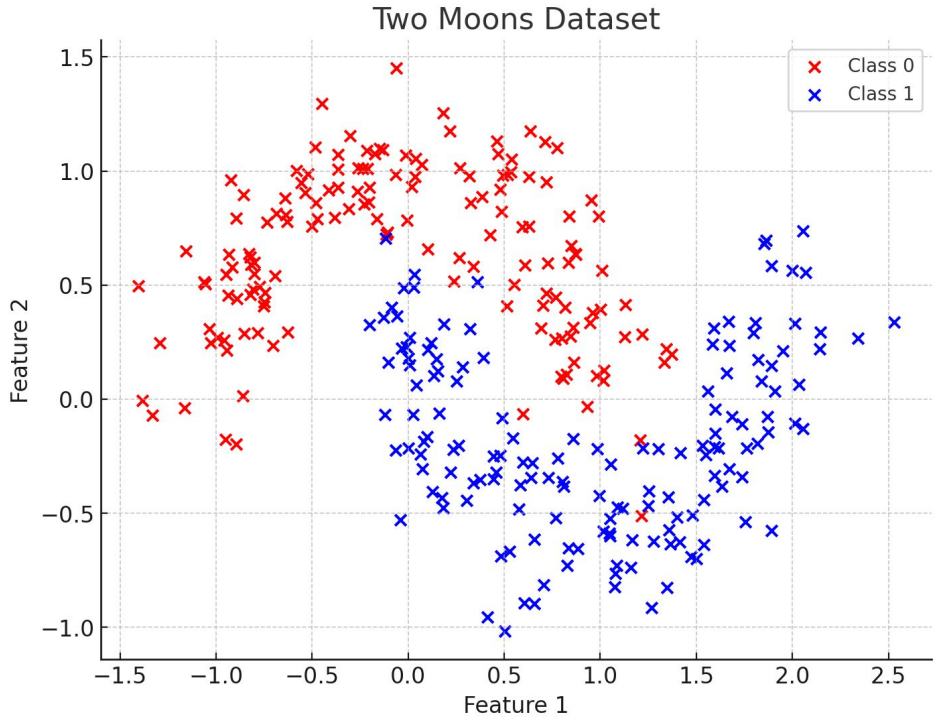
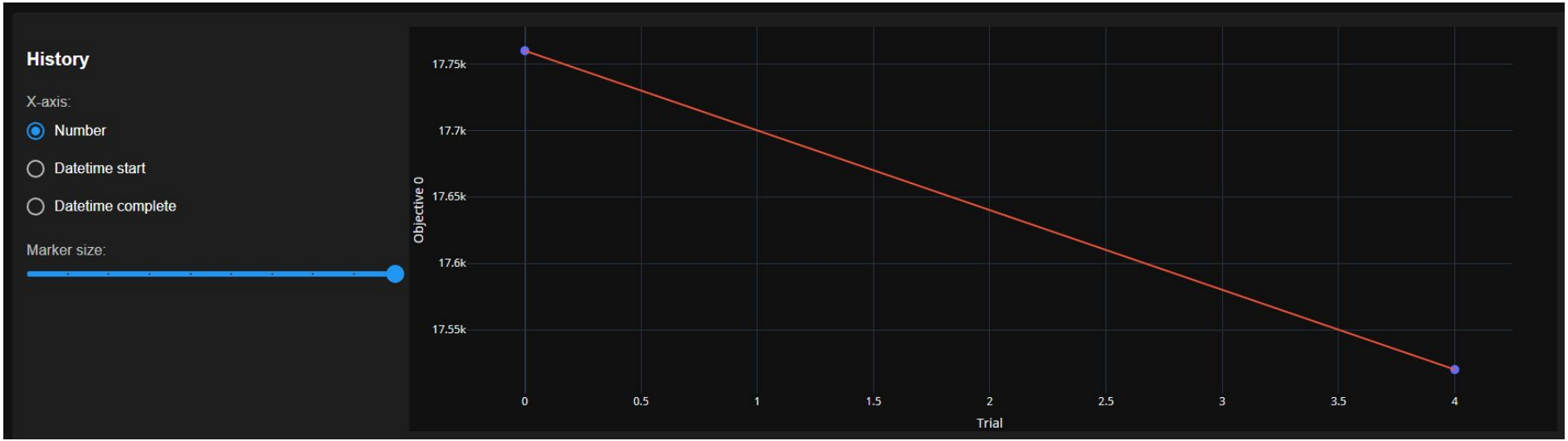
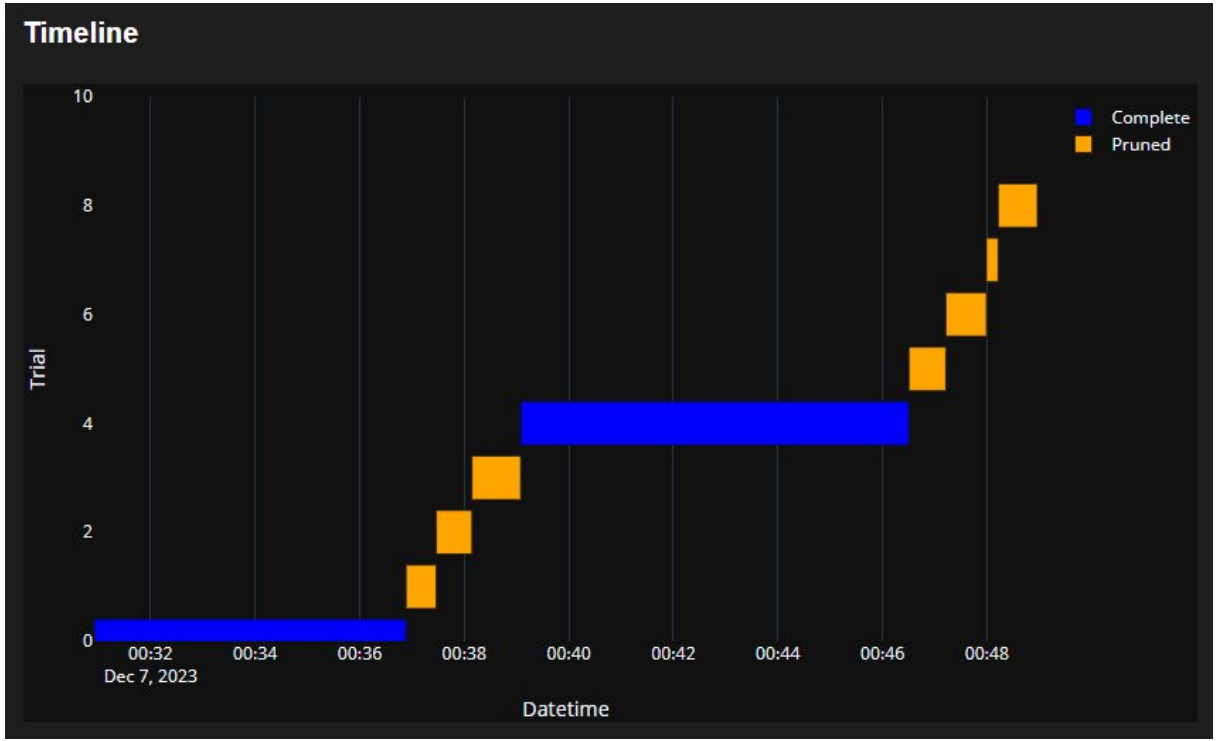
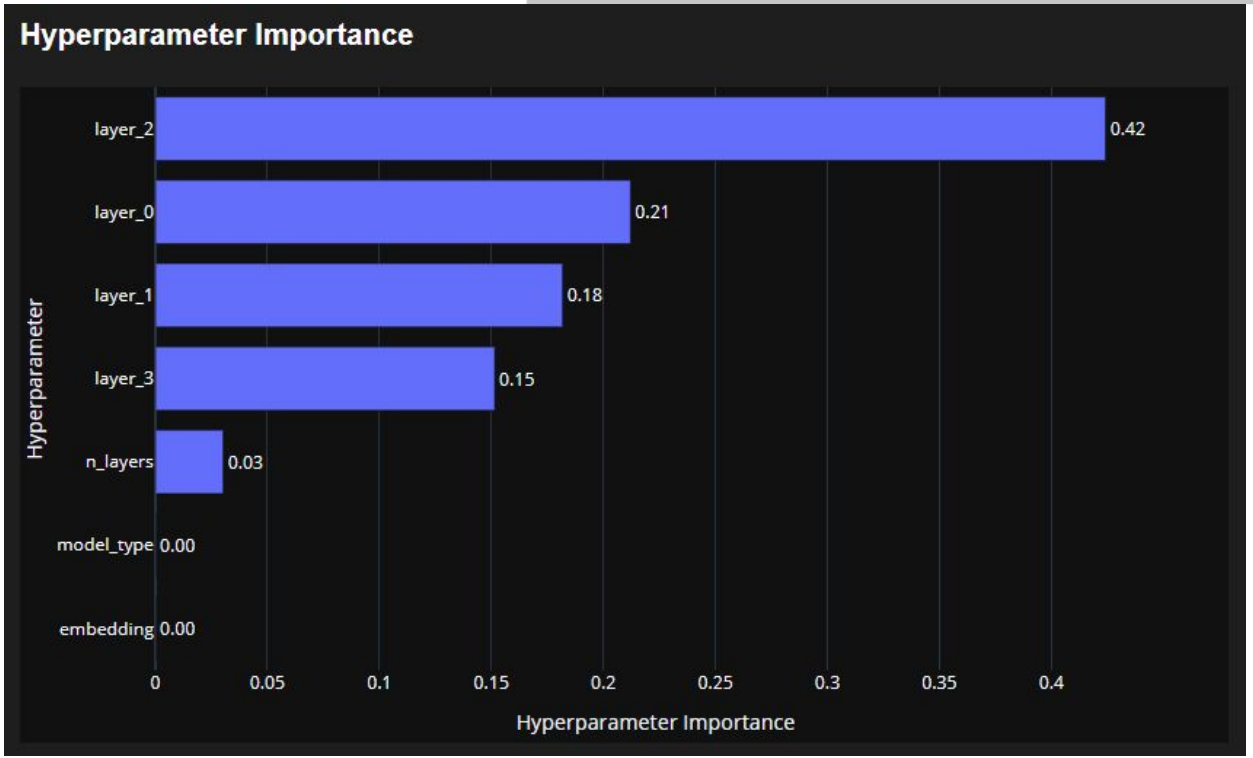

Two Moons Dataset
Class 0
Class 1
Feature 2
Feature 1
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−1.0
−0.5
0.0
0.5
1.0
1.5
2.0
2.5


History
X-axis:
Number
Datetime start
Datetime complete
Marker size:
17.75k
17.7k
17.65k
17.6k
17.55k
Objective 0
0
0.5
1
1.5
2
2.5
3
3.5
4
Trial


Timeline
Complete
Pruned
Trial
10
8
6
4
2
0
00:32
Dec 7, 2023
00:34
00:36
00:38
00:40
00:42
00:44
00:46
00:48
Datetime


Hyperparameter Importance
layer_2
layer_0
layer_1
layer_3
n_layers
model_type
embedding
0.42
0.21
0.18
0.15
0.03
0.00
0.00
Hyperparameter
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
Hyperparameter Importance

End points and discussion

Conclusions

- **Innovative Approach:** AQMLator's unique methodology of treating ansatz as a hyperparameter revolutionizes quantum circuit design in QML.
- **Optuna Integration:** The integration of Optuna for hyperparameter tuning, including ansatz optimization, enhances the efficiency and effectiveness of quantum models.
- **Practical Usability:** Compatibility with IBM and D-Wave quantum devices, along with the user-friendly Optuna Dashboard, makes AQMLator a powerful tool in the realm of quantum computing.
- **Broadening Accessibility:** AQMLator simplifies complex quantum computations, making quantum machine learning more accessible to a wider range of researchers and practitioners.
- **Future Potential:** The ongoing development and application of AQMLator promise to drive further innovations and advancements in quantum machine learning.

https://aqmlator.readthedocs.io/en/latest/

https://pypi.org/project/AQMLator/

https://git.plgrid.pl/projects/EHPCPL/repos/aqmlator/browse

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Thank you for your attention!

Questions and further discussions are welcome.