Letter of Intent for Research Software Maintenance Fund – Round 1

May 12, 2025

1 Application name

Consolidating Bonsai as the Standard for Neuroscience Intelligent Experimental Control

2 Size of grant

- ◉ Small award (up to 1 year / £150k)
- ○ Large Award (up to 2 years / £500k)

3 Proposal summary / scope of work (500 words)

Please provide a short summary of the work being proposed.

Bonsai[1] is a software ecosystem used by thousands of (mostly experimental neuroscience) users in the UK and all around the world (reference usage numbers: number of downloads, forum members, distribution around the world). Being a visual-programming language, Bonsai allows scientists with little programming experience to control sophisticated neuroscience experiments. Bonsai is the centre of a growing ecosystem of open source hardware and software ...

[1] https://bonsai-rx.org/

Machine learning (ML) is now becoming essential for most branches of science, neuroscience in particular. A few years back, ML was mostly used by statisticians, but today it is becoming a popular technology, thanks to many ML libraries (like PyTorch, GPyTorch, SickLearn) that simplify its use. Yet, current neuroscience experiments are still controlled by simple means (e.g., deliver a reward when a rat pokes left but not right). In 2022, we realised that adding ML functionality to Bonsai could empower Bonsai users and enable a radically new type of intelligent experimental control. We created the Bonsai.ML[2] package providing machine learning functionality to the Bonsai ecosystem.

We have added to Bonsai Bayesian Linear Regression models, Linear Dynamical Systems (LDS), Hidden Markov Models (HMM) and point-process decoders. We have used these models to characterise a diverse range of behavioural and neural recordings. All methods we have developed had been demonstrated using behavioural and neural data[3].

Bonsai is implemented in C#, while most machine learning models are implemented in other languages, like Python, Julia or R. To facilitate the incorporation of machine learning functionality into Bonsai, and motivate more ML methods developers to contribute their methods, we developed the Bonsai-Python Scripting[4] package and used it to interface Bonsai with ML packages written in Python.

The potential of providing machine learning functionality to experimental neuroscientists with little programming experience is large, as it could help them create unprecedented experiments leading to groundbreaking scientific findings. However, to maximise the impact of this new functionality we, as methods developers, need to invest extra efforts on documentation, training and community building, as we propose below.

The vast majority of current ML methods process data in batch form, after experiments are finished. Bonsai is a unique source of real-time behavioural and neural data, it is best suited for real-time ML methods, and should be a data source of great interest to the growing community of real-time ML methods developers. Thus, our community building activities will attempt to expand Bonsai's current user base of experimental neuroscientists with ML methods developers.

[2]https://bonsai-rx.org/machinelearning

[3]https://bonsai-rx.org/machinelearning/examples/README.html

[4]https://bonsai-rx.org/python-scripting/

Documentation: the current documentation of Bonsai.ML[5] is good; it describes the API and demonstrates the usage of packages for processing behavioural and neural data. As part of this project we will improve this documentation by:

1. providing more examples on the application of the already integrated ML methods to new types of behavioural and neural data.
2. including include video tutorials on the use of the Bonsai.ML packages.
3. adding documentation for methods developers. The current documentation is focused on experimental neuroscientists. For methods developer we will add examples and video tutorials on how to integrate existing ML packages, written in different programming languages, into the Bonsai ecosystem.
4. crucial to Bonsai.ML is to provide its users with comprehensive information about what the ML methods in the package operate, what their assumptions are, and what the generated outputs mean. We will use Bonsai.ML to provide training to its users on machine learning. An excellent resource exist presenting case studies for neural data analysis with Python[6]. We will create case studies for intelligent experimental control with Bonsai.ML.

Training: NeuroGEARS Ltd (the non-profit organisation that is the main contributor to the development of Bonsai) has organised xxx Bonsai course at different universities, and some of them can be viewed online[7]. As part of the proposed project we will organise a new Bonsai course with two tracks, one for experimental neuroscientists and the second one for methods developers. The course will start with an introduction to Bonsai common to both tracks. The experimental track will teach how to use Bonsai.ML packages. The developers track will teach the reactive programming framework and how to use different programming languages to interface with Bonsai.

[5] https://bonsai-rx.org/machinelearning/index.html
[6] https://mark-kramer.github.io/Case-Studies-Python/intro.html
[7] https://bonsai-rx.org/learn/

Community: It is important that we integrated into Bonsai ML methods that are used widely by experimental neuroscientists. It is also important that the ML functionality we provide satisfies the need of these scientists. For these reasons it is vital that we collaborate with experimental neuroscientists on the integration of ML methods into Bonsai.

Several Neuroscience institutions around the world are using Bonsai for experimental control: the Allen Institute for Neural Dynamics and Janelia Research Campus in the US, the Chamapalimaud Centre for the Unknown in Portugal, the Sainsbury Wellcome Centre in London, among others. We will reach out to experimental neuroscientists at these institutions to collaborate on the integration of machine learning functionality into Bonsai.

4 Categories of work

- ☐ Technical
- ☑ Documentation
- ☑ Training
- ☑ Community
- ☐ Governance

5 Project team (250 words)

Briefly describe why your team is the appropriate one to carry out these activities. You will be asked to provide details of the Project Lead and Co-Leads on the Team Details page, along with their connection to the software.

6 Benefit to UK research (250 words)

Briefly describe the expected value of the proposed work to UK research. You may wish to describe the fields of research or types of research method the software is used in, and describe the benefits to a particular community. You may also want to give examples of what research is enabled by the software.

7 Landscape analysis (250 words)

Briefly describe the other software (either proprietary or open source) that is primarily used by the research community addressed by the work in this proposal. Summarise, to the best of your knowledge, how the software in this proposal compares to these other software in terms of user base size, usage, and maturity. Describe, if appropriate, how the other software interacts with the software in this proposal.

8 Measure of impact (optional) (250 words)

Briefly describe how you would measure the impact of the proposed work. You may have existing measures that you use, or you may propose new measures. For the Expression of Interest we are looking to understand how you would approach this, and what you think is important to measure. In the full application, you will be asked to define specific measures.