

# NSF Proposal

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## 1 Project Summary

Lots of important work being done in biology involves data-centric models. In particular, ecological niche modelling is a process by which species presence and absence data are used in conjunction with bioclimatic data in order to predict the species's fundamental niche. Ecological niche modelling can be used to make predictions about current species distribution as well as future distributions in response to changing climate conditions. Maxent is a popular method of ecological niche modelling which applies machine learning techniques to presence-only data in order to predict the suitable range of a species. Quantum machine learning is an exciting and rapidly growing field. Quantum algorithms can often do computations in fewer steps than their classical counterparts, and this is known as quantum speedup (Biacombe et. al). Continuous variable models of quantum computing have been used to implement machine learning algorithms such as Q-learning, Proximal Policy Optimization, and others. We wish to create a quantum implementation of Maxent.

## 2 Project Description

### 2.1 Introduction

Data scientific methods of gaining information have seen an explosion of popularity in recent years. This is due in part to increased data availability, as well as advancement in database technology and machine learning techniques.

Ecological niche modelling is the process of predicting the suitable range of a species using a combination of biotic factors, abiotic factors, and mobility limitations. Biotic factors include predation and presence of food sources, while abiotic factors refer largely to climate conditions, such as average temperature and precipitation. Species mobility is also a limiting factor in species presence, as often geographic features such as mountains can separate otherwise suitable habitats.

Maxent is a method of ecological niche modelling concerned with determining the abiotic conditions required for species suitability. Maxent models take species presence data and bioclimatic data over some domain as their input, and produce estimates for suitable range and importance of each climate variable.

This information is then applied to a target range of either present climate data or forecasted future data, and is used to produce a predicted suitable range for the species.

Quantum computing makes use of quantum mechanics as a means of encoding information. Classical bits hold a value of either zero or one, and will always demonstrate this value when observed. Quantum bits, on the other hand, are often held in a superposition between zero and one, meaning there is a probability that they will collapse to zero or one when measured. Unlike classical bits, quantum bits can be entangled with one another. This means that the state of one bit is inherently related to the state of another. It is thought that quantum computers may surpass the capabilities of classical supercomputers in the coming years, an event known as quantum supremacy, and work has been done in laying down a framework for such a demonstration to take place (Boixo et al.). In continuous variable quantum computing, qubits are manipulated via a series of gates in order to do computation.

Xanadu has released a user friendly Python package called Strawberry Fields which simulates a continuous variable quantum computer. Strawberry Fields is therefore a convenient development environment for quantum computing research.

## 2.2 Objectives

We wish to create a quantum implementation of Maxent. We will do this using Strawberry Fields' continuous variable quantum simulator.

## 3 Significance

Maxent models are useful for ecological niche modelling which has biological and economic applications. The Intergovernmental Panel for Climate Change's Fifth Assessment Report predicts a global average increase of up to five degrees celsius by the year 2100 (IPCC). Maxent models can be used to model niche shift and species migration for a variety of species. Current Maxent models are costly to run, and if quantum supremacy is achieved it will be helpful to have a quantum version of Maxent prepared.

## 4 Works Cited

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IPCC, 2013: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp, doi:10.1017/CBO9781107415324.