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Computing & Engineering

The 2020 University of Chicago Undergraduate Research Symposium Proceedings: Abstract

Expanding the Indigenous Digital Footprint: Technology Access and Opportunity for Natives in the U.S.

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We study differences between the U.S. general population and the U.S. indigenous population in relation to technology access and opportunity, and look into efforts that work towards expanding the indigenous digital footprint. Research on the indigenous digital footprint is important because internet connectivity strengthens indigenous identity and by facilitating communication across indigenous groups, advances collective goals. The first research question is about basic access: given current cellular and broadband service infrastructures, how does tribal internet access compare to the rest of the United States? Part two explores educational opportunities for Native Americans interested in pursuing careers in technology and recent efforts to increase accessibility: what are the educational opportunities for Native Americans interested in pursuing careers in technology near tribal lands? What are Native American tribes doing to address the digital divide within their communities and what commonalities exist between initiatives successfully improving telecommunications infrastructure on tribal lands? Using surveys and interviews, part three reports on the experience of Urban Native Americans living in Chicago, a smart city, in regards to technology access and opportunity. Our findings matched our hypothesis: poor basic infrastructure, mainly telecommunications, disproportionately affects American Indian/Alaska Native reservations, and expanding the indigenous digital footprint requires a fostering of interest in technology fields among younger generations through the expansion and improvement in quality of available educational opportunities. To further this research topic we suggest taking a closer look at the design, security, and implementation of community network systems being developed across Indian Country, the type of internet access available at Tribal Colleges and Universities, and following-up on community initiatives that support Native Americans in tech.

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Statistical Assertions for Debugging in Qiskit

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Quantum programming is more accessible than ever, with companies like IBM providing both software tools to write quantum programs and the ability to run code on real quantum computers over the cloud. However, once a quantum program is written, how do we ensure it is correct? Since measurement disturbs the state of a quantum system, classical debugging approaches (like print statements) fail. Tools for debugging quantum programs largely do not exist. Consequently, many existing quantum programs have never been checked for errors. We implement the first debugger for IBM's Qiskit, a widely used open-source Python framework for quantum computing that is approachable to all programmers and used by researchers across institutions. Our method is based on a novel approach of making assertions on intermediate states of a quantum program and evaluating them with statistical tests. With our debugger, users create breakpoints within a Qiskit program to make statistical assertions. These should be placed at points where the expected distribution of qubit measurements is known and is one of the following quantum state categories: classical, uniform superposition, or product state. For example, assertion breakpoints can be placed before and after a Quantum Fourier Transform (QFT) within a circuit since the input state should be a uniform superposition and the output classical. Logical opposites are also supported: a "not_product" state describes an entangled state. When creating a breakpoint, the user must specify the expected state (type of assertion), the qubits of interest, and the critical p-value for passing the statistical test. Through debugging many existing programs in Qiskit Terra and Aqua (including Bell state creation, teleportation, QFT, Deutsch-Jozsa, Shor's, and Grover's algorithms), we show the usefulness of statistical assertions in novel ways for both unit testing and integration testing. This work is significant because it implements a user-friendly debugging tool for quantum programs that is available on a widely used platform and can run on both a simulator and a real quantum computer backend. This method opens up a wide range of potential applications for correcting existing programs and writing new programs without errors.

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Quasi-Neural Network: Learning Epistatic Relations and Phenotype-Genotype Interactions

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Efficient predictive models for genome-wide association studies (GWAS) remain elusive because of the lack of available data and the failure of existing learning algorithms to effectively capture structural relations within and between high dimensional biological sequences. In addition, it remains difficult to describe the complex dynamics between phenotypes and genotypes and epistatic effects among the expressed genes. To address these issues, we propose the Quasinet (Q-net), a novel machine learning algorithm that constructs conditional inference trees for every item in a sequence. We show that these trees can be used to create a new type of neural network, which we coin the quasi-neural network (QNN). Comparing the QNN with other deep learning algorithms on three GWAS tasks, we find that the QNN provides a boost in performance while using significantly fewer parameters. In addition, we show the QNN is less prone to performance deterioration when we reduce the amount of training data. Unlike existing deep neural networks, the QNN architecture is a white box model that can be used to understand the interdependencies among genes. This shows that QNN is a promising deep learning algorithm that can be applied to a variety of genomic tasks involving biological sequences.

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Creating a Heat-Dissipating Silicone Addition to Wearable Devices for Hobbyists

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Advances in personal and interactive fabrication enabled hobbyists and makers to create wearable devices. These devices provide exciting new experiences to their users, such as clothes with embedded LEDs that light up in response to the user's physical activity. Unfortunately, even the ubiquitous LED lights that makers often add to their devices are serious sources of unwanted heat. When these devices are mounted to the user's body in the form of wearables, they become uncomfortable as the heat generated by LEDs, motor drivers, etc. piles up between the wearable cover and the user's skin. While devices engineered by professionals undergo a dedicated engineering process that involves simulating heat dissipation, hobbyists currently do not have access to the knowledge or materials to create thermally sound interactive devices. To tackle this, we are creating, ThermalRouter, a system comprised of a graphical interface and a fabrication material. It assists hobbyists in creating thermally sound devices. Users access our system directly inside their CAD software while designing their devices (e.g., we made our system an add on to Autodesk's Eagle, a popular tool to design printed circuit boards). While a user designs a circuit board layout, ThermalRouter automatically identifies areas of unwanted heat and presents the user with a heat map of their design. The user can opt to improve their design by moving components around or simply ask ThermalRouter to alleviate the heat. ThermalRouter automatically runs a simulation in the background that creates an optimal layout to better distribute heat. Additionally, if users are about to wear their device in their body in the form of a wearable, ThermalRouter produces a 3D file that can be printed and used as a mold for casting an optimized piece of silicon that will improve the thermal comfort of the wearable. The user then simply follows the on-screen instructions and fills in the mold with silicon and, in special areas (annotated in the 3D printed mold), with silicon mixed with Galistan—a metal that stays liquid at room temperature and has a higher thermal conductivity than silicon, allowing us to use it as a skin-conformable heatsink.