STARTS Residency Public Report
Mark II Perceptron

Matthew Biederman, Bruno Romeira

Abstract
Mark II Perceptron is a project conceived to reflect on the research project ChipAI taking place at the International Iberian Nanotechnology Laboratory (INL) in Braga, Portugal. The foundation of the artwork is to look at the trajectory of machine learning and artificial intelligence from one of the earliest iterations, the Mark I Perceptron to the current research project ChipAI. In 1958 the Mark I Perceptron was conceived by Frank Rosenblatt, a cognitive psychiatrist at Cornell University whose research was concerned with the common housefly's sense of sight. After receiving funding from the US Office of Naval Research, he built the Mark I Perceptron, an early form of machine learning that was embodied as a custom computer. Within the ChipAI project, the underlying type of artificial intelligence uses a 'spiking neural network' which is modeled on the chemical reactions in the brain, demonstrating the field continues to be influenced by biologic processes. ChipAI hopes to solve some of the core issues in current AI methods; that of the amount of power required and the speed of computation. This project aims to establish that both the Mark I Perceptron and ChipAI have their foundation in biology. Yet the common understanding of artificial intelligence is a 'black-box' technology, opaque and invisible to anyone outside the field. For the residency, the Artist had two separate stays at INL to witness progress of the work there, and to see the beginnings of the fabrication process that will become the photonic neural network on a chip. The Artist's practice has, since the 1990's dealt with color, and electromagnetic energy directly through technological interventions and artifacts. The technical partner, INL, has been collaborating with artists previously through the VertigoSTARTS program as well as the long running SCALE TRAVELS program, of which, the Artist was also a resident with the Nanophotonics group within Romeira is based. The knowledge gained during the residency will continue to affect the Artist's career within technologies and to further his understanding of the field of machine learning and AI, specifically regarding spiking neural networks.

***Index Terms*— Artificial Intelligence, Biomorphic Computing, Interactive Art, Neural Networks, Photonics**

I. INTRODUCTION

The *Mark II Perceptron* VERTIGO STARTS residency at the International Iberian Nanotechnology Laboratory (INL) in Braga, Portugal was a collaboration between Matthew Biederman (Artist) and Bruno Romeira (Coordinator of the H2020 FETOpen Project ChipAI). Using models of spiking neural networks on embedded computing platforms, computer vison sensing, and light emitting diodes (LEDs) the artwork is an interactive, light-based sculpture reflecting on the biomorphic genesis and continuing field of machine learning and artificial intelligence. By looking at one of the earliest artifacts of machine learning, and the current trajectory of the field, the work grounds itself with the use of light (photonics) to compute and communicate, and captures the biological aspects of spiking neural networks through the literal reflection of the viewers by integrating first surface mirrors into the sculpture. One of the Artist's signatures is to use the tools and methods he is exposed to during the art-science residencies he

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has undertaken by integrating them directly into the artworks produced as a result.

II. ARTWORK

The artwork, *Mark II Perceptron* (working title), consists of a vertical plinth standing approximately 2m x 2m x 1m (W x H x D) with an offset grid (three rows of five, alternating with three rows of six to total thirty-three) circular front surface mirrors. Each mirror is 140mm in diameter and has a support in the center in order that they appear to be floating off the surface of the plinth when approached from the front. (see Figure 1). The 33 mirrors each represent a node of the spiking neural network. Mounted to the back of each mirror is a custom fabricated ring of 24 individually controllable LEDs, and each of those LEDs are individually addressable in the red, green and blue channels, theoretically making it capable of recreating any color in the visible spectrum. Microcontrollers embedded with a model of a spiking neural network based on Izhikevich's 'Simple Model of Spiking Neurons'[1] control each LED and mirror combination and represent a neuron in the network. The microcontroller network model reacts in a similar way to biologic neurons with input from either the external world in the form of light, from another 'neuron', the presence of a viewer or combination thereof with additional control for inhibition and excitation. As viewers approach the sculpture, they see a fractured reflection of themselves, which sets off a chain reaction through the artwork – a simulation of a neural network that is witnessed in real time through the flickering halos of light from behind each mirror. Waves of flickering light will pass over the surface of the plinth interfering with the reflections of the viewers.

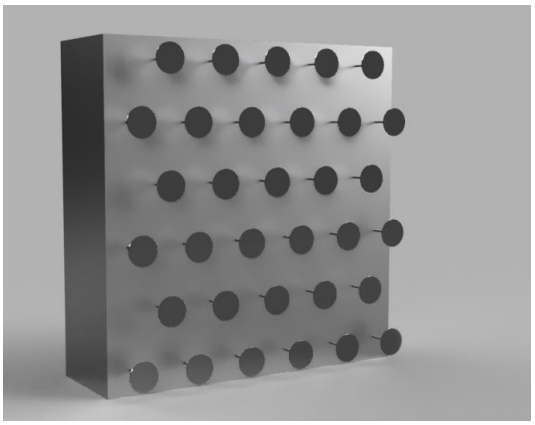
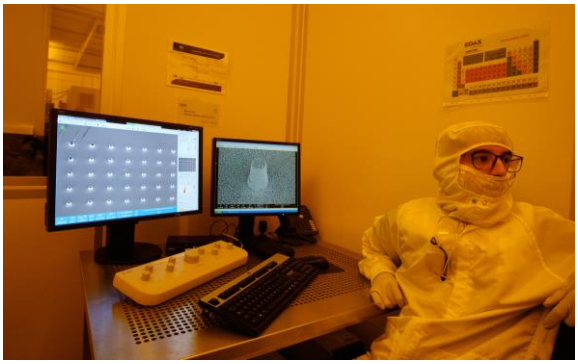


Figure 1 - Early rendering of the Artwork

The sculpture's physical form and its form of communication are derived directly from the ChipAI project. Romeira's team at INL is fabricating nanoscale structures that will communicate through photons rather than software algorithms converted to electrical charges as is the standard today. Using grids of nanoscale pillars of light, similar to the way an LED works, computation takes place through the spiking neural network and its flashes of light (see Figure 2). In turn, the sculpture's network communicates with itself, through the halos of light at a much larger scale and of course many more photons. By using the viewer's own reflection within the work, and their presence to affect the spikes and flickers, the 'life' or biologic processes that are sought to be mimicked in AI is conveyed. Each movement by the viewers sets off new spikes, but due to the way the model reacts, it is unique each time creating new and unexpected relationships.



F*igure 2 - Bruno Romeira at the Scanning Electron Microscope displaying a proto nanopillar grid*

III. METHODOLOGY

The collaboration used an iterative process of a working in order to experiment and test artwork prototypes while engaging research-production for an interactive artwork. The Artist, together with the Technology partner, designed a plan to make two visits to the INL with longer periods to work in the studio to develop ideas and experiment with techniques. Considering that the Artist had previous experience with the Nanophotonics Group at INL and was aware of the Technology project prior to the residency, integration into the team was straightforward and no lengthy introductions were required. Because of the stage the Technology project was at and the constrained timeline of the collaboration, most of the work at INL involved observing different stages of the fabrication tests and discussions surrounding biomorphic computing and its relationship to AI. Simultaneously, the Artist continued to research aspects of spiking neural networks, their theory, history, and how they work especially regarding the utilization of photonics within the ChipAI framework.

In order to keep a thread of the initial project goals intertwined, the Artist endeavored to thread a line between Rosenblatt's Mark I Perceptron, and its inception as a device to better understand biological cognition processes to the ChipAI and biomorphic computing as a central conceptual focus of the work. For the Artist, one of the main points of the work is to convey the communication of nodes (neurons) with light (photons) mimicking a function of the ChipAI on a perceptual level for the viewers. This dynamic interplay is achieved through the flickers and flashes of light representing the spikes of the network to create halos around the reflected images of parts of the viewer with the spikes travelling in waves creating a perceived network of light connecting parts of their body and presenting a visual experience of a biological and digital union.

IV. CO-CREATION PROCESS

The first months of the process involved research and reading papers about the ChipAI project and neural networks. Prior to meeting for the first time in Portugal, the Artist worked with several novel computer vision algorithms (CV) and classification systems using the TensorFlow famework with the anticipation that it would be possible to integrate these frameworks with the ChipAI system. During the first visit to INL it was clear to the Artist that the project needed to be rethought because of the stage of fabrication of the Technology. ChipAI, at that time, was only in an early stage with fabrication tests being performed to understand the impacts of scale and shape of only one particular subsystem that INL is contributing to the overall ChipAI project. It became clear that the technology itself will not be possible to integrate into the artwork as a useful component. Furthermore, due to scale, it is not possible to integrate it in any meaningful physical way as well.

At this point in the collaboration, after the first visit to INL, the Artist rethought the artwork, and began to experiment with spiking neural networks. The Artist looked at several implementations of spiking Neural Networks within the Art-Science field, such as Peter Flemming and Norman White's 'Nueromimes'[2] project and Phillip Stearns' 'AANN'[3], but these approaches were rejected as custom hardware and the fabrication time and knowledge could not meet the timeline of the project. After reviewing these different approaches with Romeira, it was decided by the Artist lithat to use of the open-source project 'Spikeling'[4] by educators BadenLabs which uses off the shelf microcontrollers with a custom circuit board. Through the construction and implementation of their algorithmic model on a microcontroller, the Artist began to experiment using these to control LED modules, and work from an intuitive position during the second phase in Portugal. During each visit, the Artist was situated with his own office and working supplies within the Photonics group zone, allowing for ample impromptu meetings, and space and time to experiment.

The Artist was invited to shadow the team at INL and witnessed their work inside the clean room, and various other labs. He had access to the tools and microscopes and observed the process of the fabrication of test prototypes for the ChipAI in order to gain an understanding of their operation. Inspired by these observations, the artwork began to take shape. The final phase, testing and fabricating the final artifact pieces, unfortunately was greatly delayed due to the coronavirus pandemic.

V. IMPACT

A. Research Impact

In the framework of the residency, a few ideas related to interfacing the artist creation with the tech development were identified. Additionally the artist shared with the tech partner a number of various additional materials related to the programming of spiking neural networks/machine learning. This can have impact in the future development and research results and outcomes related to the test of the spiking neural network target within the ChipAi project.
Importantly, the residency gave larger visibility of the ChipAI project to the general audience and improvement of the communication and exploitation of the results of the project. For example, the residency already impacted in various people including the members of the Ultrafast Bio and Nanophotonics group within INL (~15 people) and related groups within INL (>50 people), the ChipAI consortium (>30 active members) and the respective local universities/industries within the ChipAI consortium (>100 people). Other dissemination activities also increased the impact of the residency reaching >1000 people.

B. Artistic Impact

The impact on the artist and artwork is substantial in the sense that it allows for a projection into the future while looking back and considering the past histories of AI research with its starts and stops, winters and rebirths. The technical project may solve many of AI's issues, such as the power required to operate and train models, although at this stage very few solutions exist on how to train spiking neural networks. However, from a conceptual perspective the project continues to be a source of inspiration. The Artist benefitted greatly from being exposed to current trends in biomorphic computing in considering the next steps forward for the project and future project the Artist wishes to undertake.

VI. ART-SCIENCE INTER-RELATIONSHIPS

Matthew Biederman's artistic practice has been closely tied to many scientific principles, and his work relates them in a number of ways. Since 2014 Biederman (with collaborator and artist Marko Peljhan) has led the Arctic Perspective Initiative, a long term engagement in the circumpolar regions of the earth, working with community members, scientists and cultural workers in pursuing greater autonomy of the region through technology. As a member of API, he has led workshops at the Finnish Society of Bioart in Kilpisjarvi, the Academy of Arts In Tomso, and participated in panels on art and architecture of the arctic around the world. API's work has been featured at numerous art festivals and exhibitions, such as the Lyon Bienniale, Montreal Bienniale, Ice Laboratory in Moscow and Istanbul Design Bienniale among many others. Biederman's solo work also continues to straddle the line between art and science; he recently completed three works at INL during his participation in the SCALE TRAVELS residency program with the Nanophotonics group at INL. The pieces have been shown at the gnration gallery in Braga, Montreal's Elektra Gallery and the Canadian Cultural Centre in Paris, and were featured in the national newspaper of Portugal 'Publico'[5]. Furthermore, he continues his explorations in to the electromagnetic spectrum producing works that utilize radio and has been a radio amateur since 2010.

INL has hosted artists in a variety of formats, with collaborations organized through the SCALE TRAVELS program with gnration in Braga Portugal, and is beginning a MEDIA ART LAB to offer new opportunities for artists to work with researchers at the lab and create works surrounding issues explored there. They have produced a wide range of works, from audiovisual installations, to sculpture and performance based works. The lab is a beacon for art-science collaborations to modelled after and allows for open dialog and exchange between all the shareholders.

VII. FUTURE DIRECTION AND ACTIONS

The knowledge gained during the residency will continue to affect the Artist's career within technologies and to further his understanding of the field of machine learning and AI, specifically regarding spiking neural networks. In specific, the Artist will continue working on the artwork resulting from the residency, expecting to add custom components in order to answer potential exhibitors' requests. Also the Artist will be experimenting with sound integrated into the sculpture through small embedded piezo transducers into each node to sonify spatially the spiking network. Each node also could be further optimized by allowing for more inputs and various networked configurations. The work will be entered into the Artist's ouvre and offered to his network of festivals and venues with the anticipation of exhibition.

VIII. CONCLUSION

A. *Concluding Remarks*

Ultimately, the residency and collaboration at the INL resulted in a very different outcome than anticipated. However, the residency was fruitful in furthering the understanding of biomorphic computing and spiking neural networks and their modeling as a digital system rather than a biological one. The Artist is very pleased with the trajectory of the work and looks forward to further develop the artifact of the collaboration.

APPENDIX

[1] E. M. Izhikevich, "Simple model of spiking neurons," in IEEE Transactions on Neural Networks, vol. 14, no. 6, pp. 1569-1572, Nov. 2003, doi: 10.1109/TNN.2003.820440.

[2] Flemming, Peter. https://peterflemming.ca/projects/neuromimes Accessed 05/06/2020

[3] Stearns, Phillip. "*Artificial Analog Neural Network*: Conceptual and Technical Considerations." *Leonardo Music Journal*, vol. 19, 2009, p. 14-21. *Project MUSE* muse.jhu.edu/article/363694.

[4] Spikeling: a low-cost hardware implementation of a spiking neuron for neuroscience teaching and outreach
Tom Baden, Ben James, Maxime JY Zimmermann, Phillip Bartel, Dorieke Grijseels, Leon Lagnado, Miguel Maravall
bioRxiv 327502; doi: https://doi.org/10.1101/327502 Now published in *PLOS Biology* doi: 10.1371/journal.pbio.2006760

[5] Dias, Tiago Mendes. “Uma viagem às profundezas da matéria e da luz recriada à medida do olho humano” *Publico* July 29, 2018. https://www.publico.pt/2018/07/29/culturaipsilon/noticia/uma-viagem-as-profundezas-da-materia-e-da-luz-recriada-a-medida-do-olho-humano-1838124

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ABOUT THE AUTHOR

Matthew Biederman. b. 1972, Chicago Heights, IL, USA. Matthew Biederman works across media and milieus, architectures and systems, communities and continents since 1990. He creates works where light, space and sound reflect on the intricacies of perception. Since 2008 he is a co-founder of Arctic Perspective Initiative, with Marko Peljhan working on throughout the circumpolar region. Biederman was the recipient of the Bay Area Artist Award in Video by New Langton Arts, First Place in the Visual Arts category of Slovenia’s Break21. He has served as artist-in-residence at a variety of institutions and institutes, including the Center for Experimental Television on numerous occasions, CMU’s CREATE lab, the Wave Farm and many more. His work has been featured at: Lyon Bienniale, Istanbul Design Bienniale, The Tokyo Museum of Photography, ELEKTRA, MUTEK, Ars Electronica, Bienniale of Digital Art (CA), Artissima (IT), SCAPE Bienniale (NZ), among others. Biederman is currently represented by Art45 + Sedition.com and lives and works in Montreal, Quebec.

Bruno Romeira is a staff researcher at the Ultrafast Bio- and Nanophotonics group and coordinator of the H2020-FET-OPEN project “ChipAI”. His research cuts across several disciplines in applied physics and engineering, which include semiconductor physics, low-dimensional nanostructures and nanophotonic and neuromorphic devices. He received the PhD degree of physics (summa cum laude) and the title of European PhD from the University of the Algarve, Portugal, jointly with the University of Glasgow, U.K., and the University of Seville, Spain, in 2012. He then held a Post-Doctoral Fellowship at the Microwave Photonics Research Laboratory, University of Ottawa, Canada (2013–2014), and a Marie Skłodowska-Curie Research Fellowship at the Applied Physics Department and Institute for Photonic Integration of the Eindhoven University of Technology (2015–2017). He then joined the International Iberian Nanotechnology Laboratory (INL), Portugal, as a Marie Curie COFUND research

fellow before being appointed a staff researcher at INL. Bruno Romeira received the “Young Researchers Incentive Programme” Award from the Calouste Gulbenkian Foundation, Portugal, in 2009. He was a recipient of the “2011 IEEE Photonics Society Graduate Student Fellowship,” from the IEEE Photonics Society, USA. He also received the “Best PhD Thesis in optics and photonics in Portugal in 2012” from the Portuguese Society of Optics and Photonics. He is a member of the Optical Society of America (OSA), the USA, and a member of the IEEE and the IEEE Photonics Society, USA.

Matthew Biederman website: http://www.mbiederman.com/
Tech Project (ChipAI) website: https://www.chipai.eu/
Mark II Residency at STARTS Residencies platform: https://vertigo.starts.eu/calls/starts-residencies-call-3/residencies/mark-ii-spiking-perceptron/detail/