Tiny trainable instruments

by

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Abstract

Tiny trainable instruments is a collection of instruments for media arts, using machine learning techniques and deployed in microcontrollers.

Thesis Supervisor: Tod Machover
Title: Muriel R. Cooper Professor of Music and Media

Acknowledgments

UROPs Peter Tone, Maxwell Wang

Opera of the Future

Future Sketches

Family and friends

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Chapter 1

Introduction

1.1 Context

This thesis is the capstone project of my master's program, between the academic years 2019-2

The work presented here has been developed mostly working remotely during the COVID19 pandemic.

TODO: include photograph of my desk at home.

As part of the research that directly informed this thesis, I highlight the classes I took, including:

1. Comparative Media Studies, by Sasha Costanza-Chock
2. Recreating The Past, by Zach Lieberman

Some other projects I created during these years include:

1. SiguesAhi
2. Open Drawing Machine, with Gaurav Patekar
3. Introduction to networks for artists

Opera of the Future Future Sketches 2019-2021

1.2 Section sample

1.2.1 Subsection sample

1. Item 1.

Chapter 2

Background

2.1 Instruments

The table 2.1 is an example of media arts instruments that are scriptable.

Maker	Instrument	Year	Computing	Software
BASTL	microGranny 2	YEAR	microcontroller	Arduino
BASTL	Kastle v1.5	YEAR	microcontroller	Arduino
Critter & Guitari	Organelle	YEAR	computer	Linux?
Critter & Guitari	EYESY	YEAR	computer	Linux?
monome	aleph	YEAR	computer	Linux?
monome	norns	YEAR	computer	Linux
Shbobo	Shnth	YEAR	microcontroller	ARM Cortex
Shbobo	Shtar	YEAR	microcontroller	ARM Cortex

Table 2.1: Table of media arts scriptable instruments

2.1.1 BASTL

BASTL Kastle, two iterations and a spinoff: Kastle, Kastle v1.5, Kastle Drum.

Based on Arduino, GitHub repository with alternate firmware.

Breadboard patching with jumper cables, inputs and outputs robust enough to allow for mistakes in connections.

2.1.2 Critter & Guitari

Organelle computer for sound, scriptable, Linux operating system + Pure Data software.

ETC and EYESY computers for visuals, scriptable, Linux operating system + Python / pygame environment or openFrameworks.

2.1.3 monome

Aleph: sound computer

Norns: sound computer, currently on its second iteration, with expanded hard drive. Also there is a DIY versionm which is cheaper and runs on a Raspberry Pi. Norns is a Linux machine, running SuperCollider for the sound engine, and Lua scripts.

2.1.4 Shbobo

Peter Blasser's Shbobo

Shnth and Shtar

Shlisp language and Fish IDE.

github.com/pblasser/shbobo

2.2 Education

Mitch Resnick's book Lifelong Kindergarten

Low floor, wide walls, high ceiling

Peers, projects, passion, play

Gene Kogan and Andreas Refsgaard

2.3 Machine learning

ml5.js

Runway

TinyML Professional Certificate HarvardX

2.4 Digital rights

Electronic Frontier Foundation

Edward Snowden

Design Justice Network

Chapter 3

Early experiments

3.1 Microcontrollers

My first exposure to Arduino was as an undergraduate student of electrical engineering back home in Chile. The Arduino Uno was a very powerful device, and I saw its applications to arts, when with a friend we created a rudimentary automatic tuner for guitar, that performed pitch detection and then controlled a motor to move the tuning machine on the guitar to achieve the desired tuning, with a PID controller.

I didn't use it too much, because they were relatively hard to obtain, and I was more interested in software at the time.

Fast forward to 2015, I became a graduate student at New York University's Interactive Telecommunications Program, where on my first semester I took the amazing class Introduction to Physical Computing, with one of Arduino's co-creators Tom Igoe.

While freelancing in New York, I was introduced to an Arduino off-shoot, the Teensy, which captivated me by its USB MIDI capabilities, which allowed for standalone operation without a host computer, and by its audio library, which allowed me to create interactive standalone experiences, triggering samples and applying audio effects on device.

While at MIT Media Lab, I was delighted by the newer versions of Teensy, which are even faster and more powerful, and which led me to start designing handheld samplers for field recordings.

This in turn led me to review the current NYU ITP materials for physical computing, where they currently stopped using the now classic Arduino Uno, and have incorporated

3.2 Machine learning

Class at School of Machines by Gene Kogan and Andreas Refsgaard on 2018.

ml5.js

Machine learning for artists

Piano Die Hard with Corbin Ordel at the alt-ai conference, with Wekinator and KNN algorithm.

ml5.js is a wrapper for Tensorflow.js, NYU ITP. Browser based

Runway ML by Alejandro Matamala, Anastasis Germanidis, and Cris Valenzuela.

Casey Reas' book for GANs.

Chapter 4

Tiny trainable instruments

4.1 Design principles

1. Cheap
2. Privacy

4.2 Technology

This project is based on an Arduino Nano 33 BLE Sense.

Arduino microcontroller

Arduino library KNN

TensorFlow Lite Micro

4.3 Programmable / remix

4.4 Philosophy and experience

4.5 Inputs

Enumerate sensors from the Arduino Nano 33 BLE Sense.

4.5.1 Color

This approach uses the RGB color sensor from the microcontroller, with the auxiliary help from the proximity sensor, that is used to capture color information at a certain distance threshold.

The data is passed to a k-Nearest-Neighbor algorithm, programmed using the Arduino KNN library.

4.5.2 Gesture

This input uses the information from the Inertial Measurument Unit (IMU) of the microcontroller, including a gyroscope and accelerometer. It captures data after a certain threshold of movement is detected.

The data is passed to a TensorFlow neural network, programmed using the Arduino TensorFlow Lite library, and based on the included magic_wand example.

4.5.3 Speech

This input uses the information from the microphone of the microcontroller.

The data is passed to a TensorFlow neural network, programmed using the Arduino TensorFlow Lite library, and based on the included micro_speech example.

4.6 Outputs

The different outputs were picked, because of their low cost, ubiquity, and possibilities of expansion and combining them.

4.6.1 Buzzer

This output creates pitched sound, by using a PWM output.

4.6.2 Servo motor

This output creates movement and through that, rhytmic sounds.

4.6.3 MIDI

We wrote functionalities to manipulate MIDI innstruments, and included examples to interface with some popular and cheap MIDI instruments, such as the Korg volca beats.

4.6.4 Thermal printer

A thermal printer is the basis for creating written and literary output, inspired by the field of computational poetry.

4.7 Development

This thesis has been developed with the invaluable help of undergrad researchers Peter Tone and Maxwell Wang.

They have cloned both repositories, the main one and the Arduino library one, and have continuously submitted pull requests with their contributions.

Peter Tone has helped with research in data structures, library writing, and we have shared back and forth code, going from experimental proofs of concepts, and has also helped with the design of the user-facing library.

Maxwell Wang has proofread our code, has ran the examples, and has helped with the writing of the documentation for self-learners and for the workshops.

We all share a Google Drive folder, where we all share notes about our research and development of the library and the educational material.

4.8 Code

This thesis is distributed as a repository, hosted on the GitHub platform, and available at https://github.com/montoyamoraga/tiny-trainable-instruments.

The auxiliary files, such as the LaTeX project for this document, and the auxiliary

Jupyter notebooks, and documentation and tutorials are on the repository .

The code of this thesis is written in C++, and is packaged as an Arduino library.

It is distributed through the repository https://github.com/montoyamoraga/TinyTrainable and also available through the Arduino IDE.

4.9 Opera of the Future projects

During the development of this thesis, I have been fortunate to collaborate on different capacities with other thesis by classmates at Opera of the Future, which has directly informed my work.

Squishies, Hannah Lienhard's master's thesis, novel squishable interfaces for musical expression. We shared discussions about low-level sound design, code reusability, sound art education, digital instruments.

Fluid Music, Charles Holbrow's PhD thesis, library design, documentation for contributors.

Chapter 5

Project evaluation

5.1 Digital release

This thesis lives on the internet on repositories, and at the MIT library.

The repositories are hosted on GitHub, to promote collaboration, and people can file issues and pull requests.

GitHub repository

Arduino library

PDF zine for explaining, reference as the PDF booklet for monome norns

5.2 Audience engagement

5.3 Workshop

Applied to grant at CAMIT for teaching the workshops in English in USA, and in Chile in Spanish, remotely over Zoom.

Each workshop consists of 2 sessions of 3 hours each, spread over a weekend.s

5.4 Multimedia show

Livestreamed show with multiple artists incorporating Tiny Trainable Instruments to their practice.

Chapter 6

Conclusion

This thesis project is a

6.1 Future work

6.1.1 Education

I hope that this thesis project is adopted by educators, to introduce students to machine learning, physical computing, media arts, and ethics.

6.1.2 Artist workflow

Training instead of programming.

6.1.3 Packaging

Low hanging fruit is to package a Tiny Trainable Instrument with a set of particular outputs, on a perfboard or PCB.

The next step would be to create enclosures.

6.1.4 Gallery

Bibliography