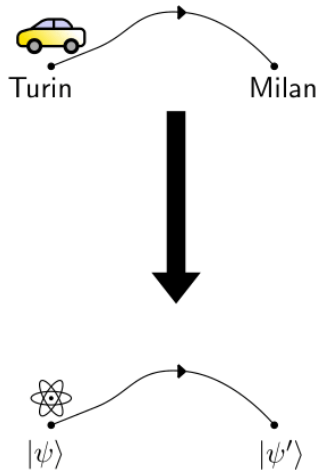
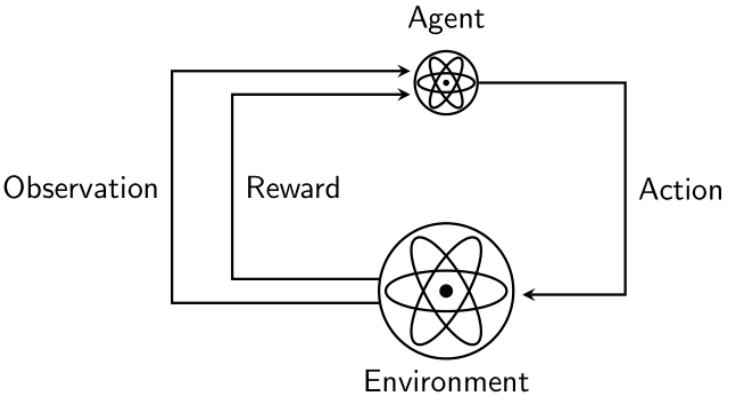
RESEARCH PROJECTS

Quantum circuit design with reinforcement learning

Master Thesis under Professor Davide Girolami supervision - Polytechnic of Turin





Short abstract

Trained a reinforcement learning agent (*Temporal difference learning with linear function approximation* algorithm) to design a quantum circuit capable of transforming an initial quantum state into a given target state.
This is a very common problem in quantum computing, and the goal is to minimize the number of gates. The problem has been modeled as a shortest path problem, intuitively similar to moving from one city to another by car.

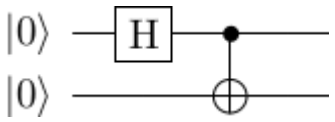
Tools and frameworks

- Python
- Qiskit (real quantum circuits programming language)
- IBM Quantum Lab - accessibility of quantum hardware on the cloud

Constraints and results

- Algorithm applied to systems of 2 qubits.
- Similarity between target and terminal state measured with fidelity,
- Experiments on Bell States (very well known 2-qubits quantum states, showing interesting properties): optimal or close to optimal results, with fidelity between 0.93 and 1 over four different target states
- **Awarded best thesis** among those presented to the commission

Designed circuit **example:**

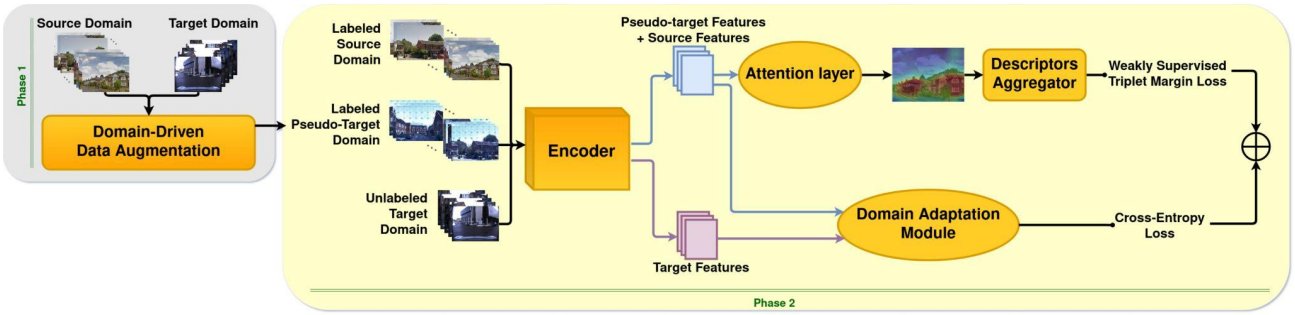


Resources

- Code
- Manuscript
- Presentation slides

Visual Place Recognition

Two months research internship at VANDAL Laboratory - Polytechnic of Turin.
Work supervised by Professor Barbara Caputo, Senior Postdoc Carlo Masone, PhD candidate Gabriele Moreno Berton



Short abstract

We address the task of cross-domain visual place recognition, where the goal is to geolocalize a given query image against a labeled gallery, in the case where the query and the gallery belong to different visual domains (e.g. different light conditions, weather conditions, ...). To achieve this, we focus on building a domain robust deep network by leveraging over an attention mechanism combined with few-shot unsupervised domain adaptation techniques, where we use a small number of unlabeled target domain images to learn about the target distribution. With our method, we are able to outperform the current state of the art while using two orders of magnitude less target domain images. Finally we propose a new large-scale dataset for cross-domain visual place recognition, called SVOX

My job

Originally *Phase 1* (figure above) domain adaptation layer has been implemented with a neural network requiring ~2 training days on GeForce GTX 1080 GPU.
My job consisted of **implementing an unsupervised domain adaptation block** using Fast Fourier Transform, such that representations from different domains could be learned. The original architecture used a neural network for this step, making the process time and energy consuming. Additionally, it needed tens of images from the target domain in order to perform well on the adaptation task.
The new algorithm needs only a single target domain image and no training at all: given a target and a source domain pictures, Fourier Transform is applied to both. Then, some frequencies from the target are substituted into the source, achieving the desired domain adaptation: in this way, we obtain a labeled image in the target domain.

I also spent a large amount of time making experiments to compare the results of the new architecture with those coming from the original one.

Tools and frameworks

- Python
- PyTorch

Results

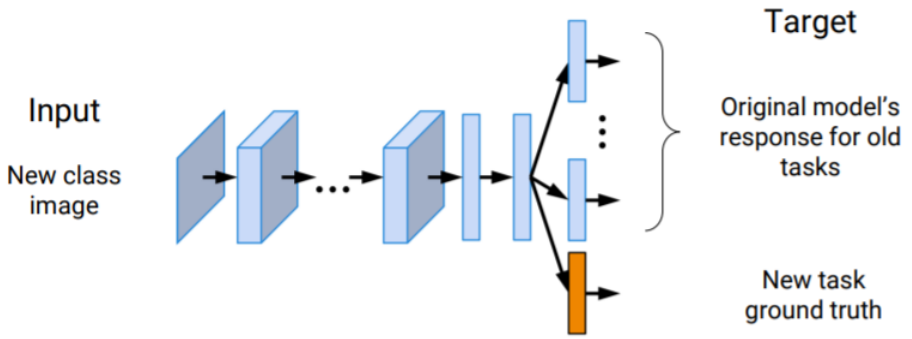
- Increment of 1 point on average recall over all adaptation domains.
- Interpretability of the algorithm.
- No training needed for the new domain adaptation block: a lot of time saving.

Resources

- Code
- Original paper (pre print of the new paper submitted to Frontiers in Computer Science on the 25th November 2021)

Incremental Learning in Image Classification

Two months research project for the Machine Learning and Deep Learning course.



Short abstract

Extending the knowledge of a model is an open problem in deep learning. A central issue in incremental learning is catastrophic forgetting, resulting in degradation of previous knowledge when gradually learning new information, in our case new classes in an image recognition task. The following **incremental approach** has been used for training and validation: the dataset is split into ten batches of ten classes each, with classes randomly assigned to a batch. At each learning step, the network is trained on a batch of data and evaluated on a test set that contains all known classes up to that point.

The **scope of the project** was:

1. **Reproduce some existing baselines** that address the difficulties posed by incremental learning. See iCaRL paper for details.
2. **Ablation study** on existing frameworks in order to gain a deeper knowledge of their components and in-depth insights + **define new approaches** to overcome existing limitations
   During our studies, we pointed out the following behaviours:
   - Drift in features representations of *old* classes: quantify how much representation of a fixed class change from one incremental learning steps to the next ones. Basically it emerges a **reduction in the variance of representation of older classes**, which entries tend to converge mean value. We mitigated this effect by introduction of a **new contribution to the loss** function.
   - Despite a distillation loss [Hinton et al.] contribute to encourage predictions on *old* classes of the incremental setting, we observed, as expected, a tendency to privilege predictions of classes belonging to the *new* batch. Given N training steps (corresponding to N batches), targets for the distillation loss are provided by the network trained at step N-1 (which is freezed and stored): these targets will privilege predictions of classes belonging to the N-1 batch, penalizing *older* batches.
     We **redefined distillation targets**, using for entries corresponding to classes of batch M < N the network trained at step M < N.

Tools and frameworks

- Python
- PyTorch
- Google Colab

Results

- **Increment of 1%** average **accuracy** over state-of-the-art method iCaRL
- Exam score: 30 / 30, **top 3% of the course**

Resources

- Code
- Paper
- Presentation slides

ACM RECSYS 2021

RecSys 2021 challenge organized by ACM & Twitter - MALTO Machine Learning team of Polytechnic of Turin

Short abstract

The challenge focuses on a real-world task of tweet engagement prediction in a dynamic environment. The goal is to predict the probability for different types of engagement (Like, Reply, Retweet and Retweet with comment) of a target user for a set of tweets, based on heterogeneous input data. To this end, Twitter released a ~1B samples dataset.
Most of the work of our group involved data exploration and feature engineering starting from a small set of attributes from the dataset.
We developed an internal framework, i.e. a ***feature store***, for fast deployment of new features combinations and test of their performance.
Unfortunately the workload was too much for the size of the group, so we did not manage to make the final submission. Nevertheless, we are going to participate to the 2022 task, where all of this work is going to be a very handy boiler plate to start with.

Tools and frameworks

- Python
- PySpark
- YARN cluster
- H2O library for running XGBoost on a distributed architecture

Resources

- Code
- Challenge

AUTOMATIZED INFORMATION RETRIEVAL FROM TWITTER

Two months research internship project at LINKS Foundation (based in Polytechnic of Turin), in collaboration with *Regione Piemonte*. Worked under the supervision of PhD candidate Edoardo Arnaudo, researcher at LINKS Foundation and at VANDAL Lab.

Short abstract

I have been asked to automatize the real time retrieval of numerical and alphabetical information from a stream of Twitter posts. The solution I found and implemented is a deep neural network with question and answering capabilities: I hardcoded the queries of interest inside of the algorithm, such that for a tweet given as input to the network, it returns an answer for each of the given questions. This algorithm is meant to be deployed by *Protezione Civile Piemonte*, in order to **automate real time impact estimation during emergencies**. For clarity, one example of the information retrieved by the algorithm is the number of injured people during the ongoing emergency. For this goal, the hardcoded query in the neural network is "How many people injured?" and the outcome is a number.

Tools and frameworks

- Python
- JavaScript and HTML (for customization of the labeling platform)
- PyTorch

Resources

- Code

OTHER PROJECTS

GENERATIVE ADVERSARIAL NETWORK FOR NFT ART GENERATION

Personal project on Generative Adversarial Network use in art and design.

Short description

I implemented a pipeline to scrape data from the internet, feed them to a GAN algorithm (Style-GAN2 ADA by NVIDIA). I trained several neural network with the purpose of selling NFT (I just wanted a project to explore a blockchains and NFT market) and design of apparels.

Tools and frameworks

- Python
- Selenium / BeautifulSoup for scraping
- Various scraping tools
- Tensorflow and PyTorch

Resources

- Code

SYNCHRONIZATION PHENOMENA IN OSCILLATING NON LINEAR SYSTEMS

Bachelor degree thesis project under the supervision of professor Andrea Lamberti.

Short abstract

Small project to study synchronization in oscillating non linear systems. In particular, I focused on the study and derivation of synchronization of light emission in fireflies groups, see above picture), as well as in *Josephson junctions* (two superconduction materials separated by an insulating layer), based on tunnel effect of *Cooper pairs*, which are responsible for superconductivity phenomena. Basically this work was aimed at studying how oscillations in Cooper pairs could be described by an equation formally identical (formally meaning that of course involved measurables are different, but the equations hold the same form).

Results

Thesis **evaluated with honors** (maximum score)