

Quantum Genetic Programming

Mircea-Marian Popa
Enrique de la Torre
Dmitry Grinko

What is Genetic Programming about?

1. Produce an initial randomly generated *population* of *chromosomes*, which consist of *genes*
2. Get a subset of these population and find the fittest with respect to some *fitness metric*
3. Apply *evolution* and/or *mutation* and/or *crossover* in order to get the *offspring*
4. If the *offspring* has a better *fitness* score than the previous winner solution, you keep it
5. Keep iterating until you find a perfect solution or you reach the limit of iterations

The concept of quantum genetic programming

1. **Genes** are qubits
2. **Chromosome** is a product state of these qubits
3. **Crossover** is a set of SWAP-gates applied on a two subsets of genes
4. **Evolution** is some unitary gate on the chromosome
5. Measure the chromosome (**mutation** is represented by a noisy measurement). We get a bit string
6. This bit-string encodes the object of interest. Remember: our aim is to optimize over the space of these objects.
7. Evaluate the fitness of all bit-strings. Keep the best. Adjust the evolution. Repeat.

The problem

- **Find the circuit which implements some given boolean function**
- This problem can be extended to (not implemented in this project):
 - Find a unitary which maps a set of input states into a set of output states
 - Find a *symbolic* unitary which maps some *symbolic* input state into *symbolic* output states

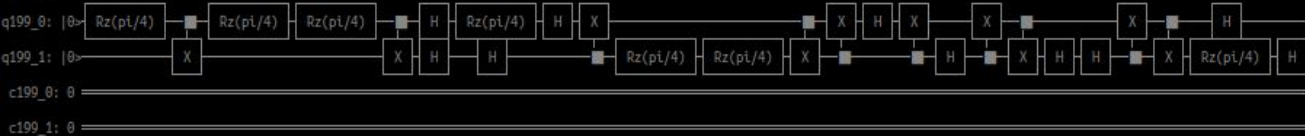
v1: Another quantum genetics algorithm

- A quantum chromosome is a ordered list of quantum genes
- A quantum gene is a Qiskit circuit
- A single quantum chromosome can represent the entire population
- Each time we measure this chromosome to get a bit string, we apply the noise configuration from an actual IBM quantum processor
- A bit string is translated into a circuit by applying a simple map that relates a fixed number of bits to a quantum gate and its inputs
- We get the fitness score for this circuit and if it is better than the previous winner, we keep it and update the chromosome applying Ry gates in order to make the chromosome converge toward the solution

Exec. script: <https://github.com/quantumgenetics/quantumgenetics/blob/master/main.py>

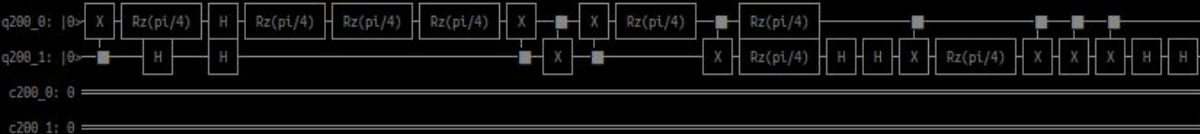
v1: Another quantum genetics algorithm

```
WARNING: _main_:Running generation 198
WARNING: _main_:Producing candidate...
WARNING: _main_:Candidate produced (12.271555 s)
WARNING: _main_:Candidate circuit:
```



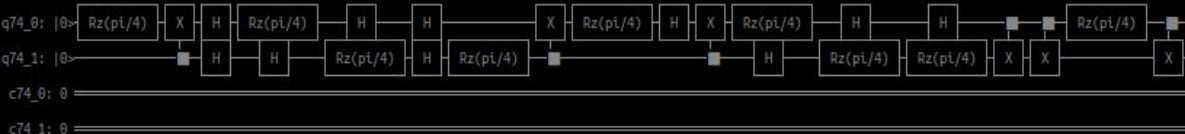
```
WARNING: _main_:Candidate eval: (((('00', {'01': 1024}, {'00': 747, '01': 139, '11': 20, '10': 118}), ('01', {'00': 1024}, {'00': 130, '01': 741, '11': 131, '10': 22}), ('10', {'10': 1024}, {'00': 24, '01': 130, '11': 739, '10': 131}), ('11', {'11': 1024}, {'00': 117, '01': 26, '11': 121, '10': 760}))), 7150)
WARNING: _main_:Current winner eval: (((('00', {'01': 1024}, {'00': 132, '01': 630, '11': 141, '10': 121}), ('01', {'00': 1024}, {'00': 639, '01': 130, '11': 116, '10': 139}), ('10', {'10': 1024}, {'00': 112, '01': 120, '11': 116, '10': 676}), ('11', {'11': 1024}, {'00': 129, '01': 130, '11': 641, '10': 124}))), 3020)
```

```
WARNING: _main_:
WARNING: _main_:
WARNING: _main_:Running generation 199
WARNING: _main_:Producing candidate...
WARNING: _main_:Candidate produced (10.48968 s)
WARNING: _main_:Candidate circuit:
```



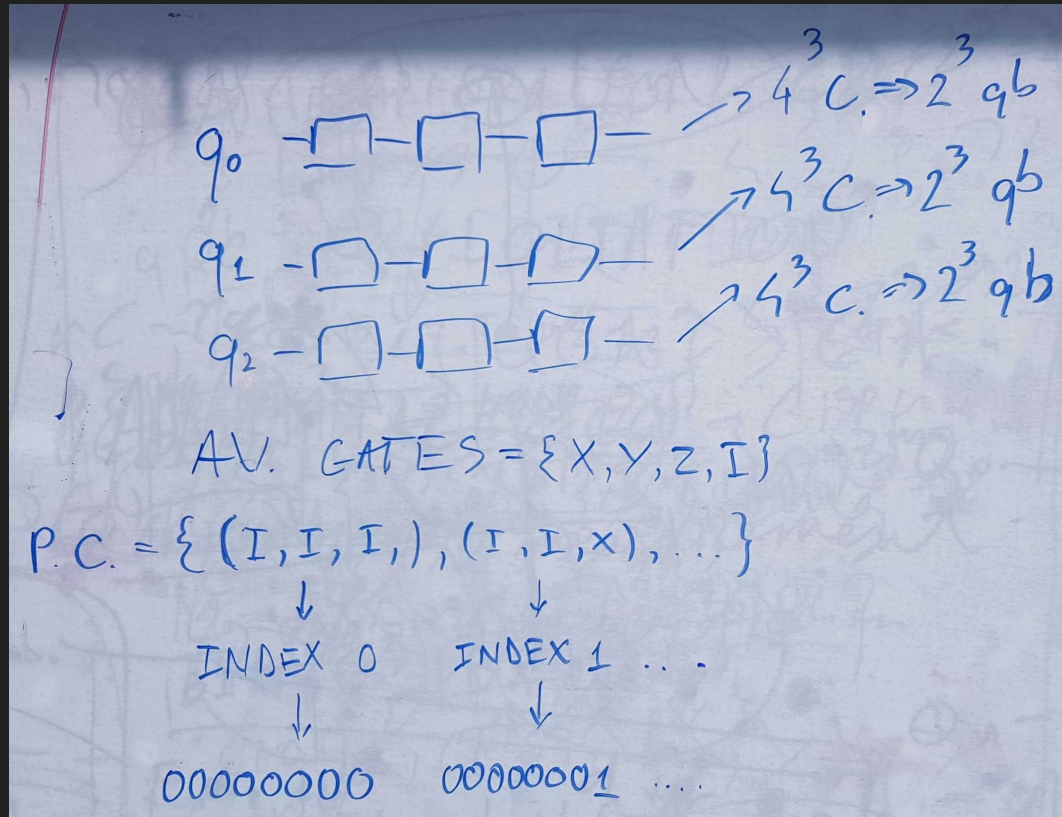
```
WARNING: _main_:Candidate eval: (((('00', {'01': 1024}, {'00': 520, '10': 504}), ('01', {'00': 1024}, {'00': 493, '10': 531}), ('10', {'10': 1024}, {'01': 528, '11': 496}), ('11', {'11': 1024}, {'01': 502, '11': 522}))), 6162)
WARNING: _main_:Current winner eval: (((('00', {'01': 1024}, {'00': 132, '01': 630, '11': 141, '10': 121}), ('01', {'00': 1024}, {'00': 639, '01': 130, '11': 116, '10': 139}), ('10', {'10': 1024}, {'00': 112, '01': 120, '11': 116, '10': 676}), ('11', {'11': 1024}, {'00': 129, '01': 130, '11': 641, '10': 124}))), 3020)
```

```
WARNING: _main_:
WARNING: _main_:
WARNING: _main_:Winner circuit:
```



```
WARNING: _main_:Winner eval: (((('00', {'01': 1024}, {'00': 132, '01': 630, '11': 141, '10': 121}), ('01', {'00': 1024}, {'00': 639, '01': 130, '11': 116, '10': 139}), ('10', {'10': 1024}, {'00': 112, '01': 120, '11': 116, '10': 676}), ('11', {'11': 1024}, {'00': 129, '01': 130, '11': 641, '10': 124}))), 3020)
```

v2: Alternative embedding of the circuit into the



GitHub repo: <https://github.com/quantumgenetics/quantumgenetics>

Thanks for your attention !