

Genetic algorithm for Quantum Support Vector Machines

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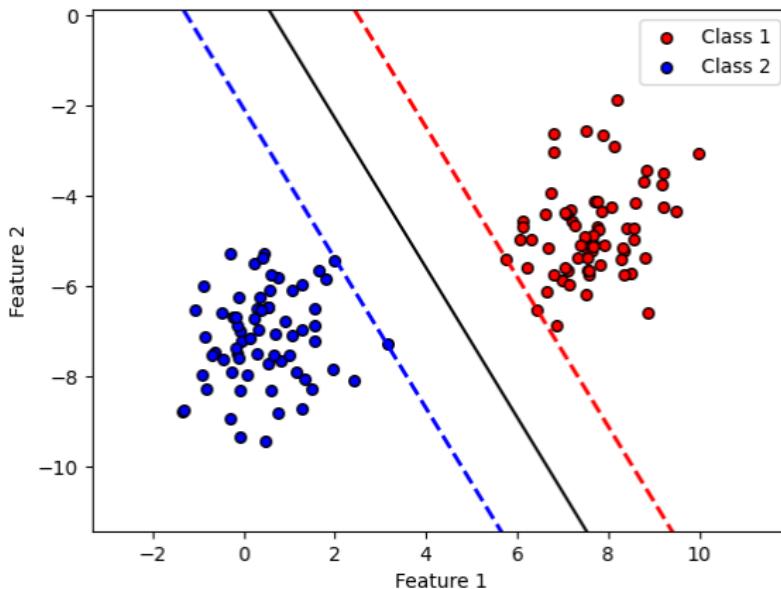
25 Novembre 2024

Quantum Machine Learning + Genetic Algorithm



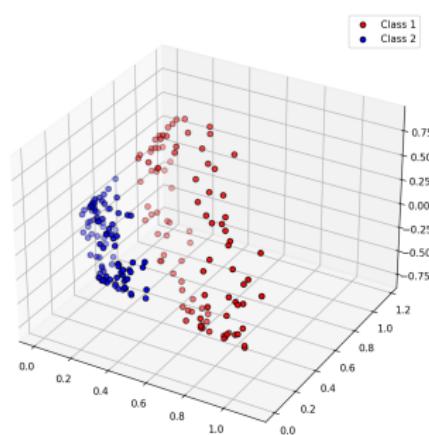
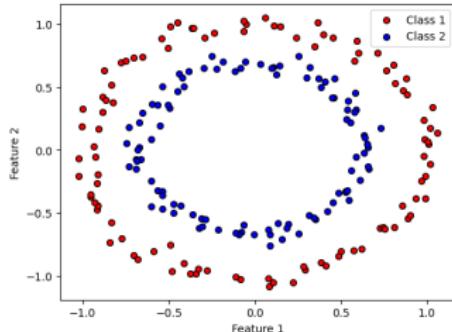
Support Vector Machine

- La SVM è un algoritmo supervisionato di classificazione binaria.



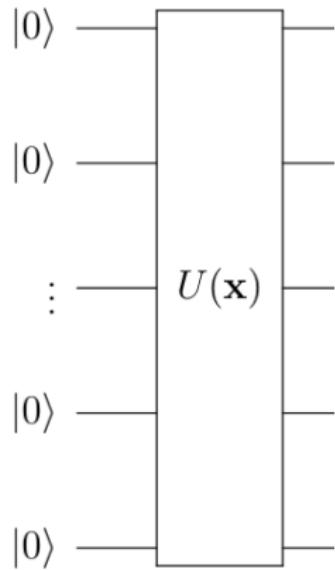
Kernel Support Vector Machine

- Nel caso in cui i dati non siano linearmente separabili?
- È possibile applicare una feature map $\phi(\mathbf{x})$.
- $K_{ij} = \langle \phi(\mathbf{x}_i), \phi(\mathbf{x}_j) \rangle$.



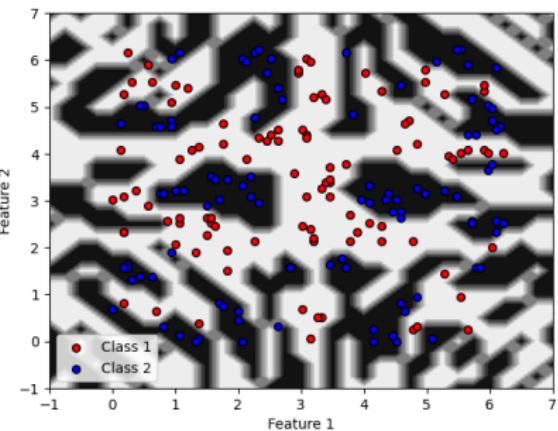
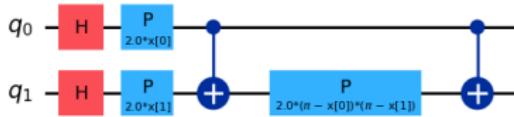
Quantum Support Vector Machine

- La feature map diventa un circuito quantistico parametrizzato.
- $|\phi(\mathbf{x})\rangle = U(\mathbf{x})|0\rangle^{\otimes n}$.
- $K_{ij} = \langle\phi(\mathbf{x}_i)|\phi(\mathbf{x}_j)\rangle$.



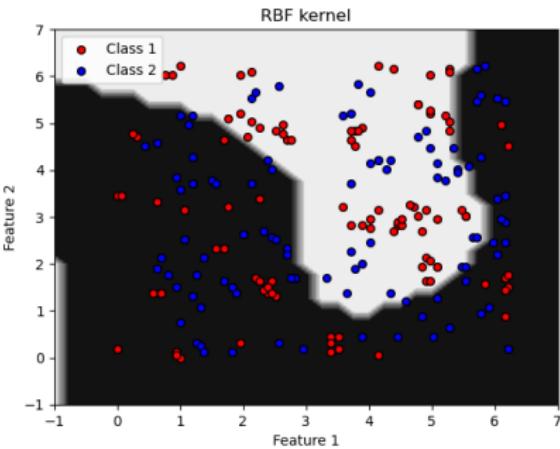
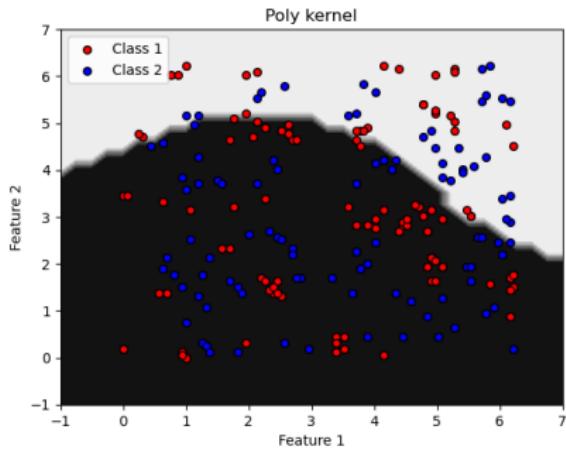
Quantum Kernels

- Un esempio: la ZZ Feature Map.
- Ottime performance su dataset complessi.



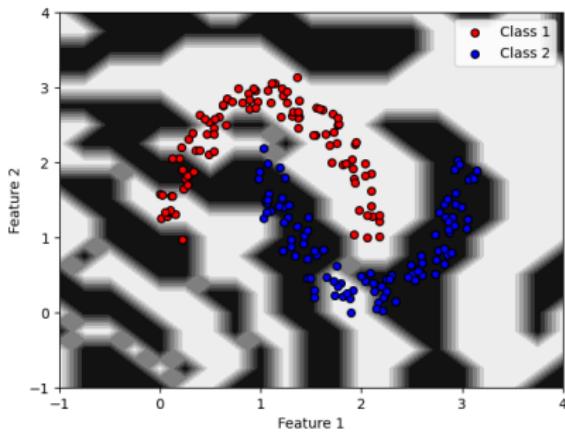
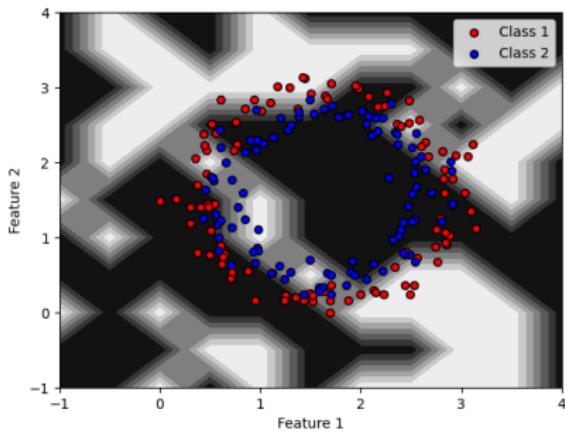
Quantum Kernels

- I metodi classici falliscono.



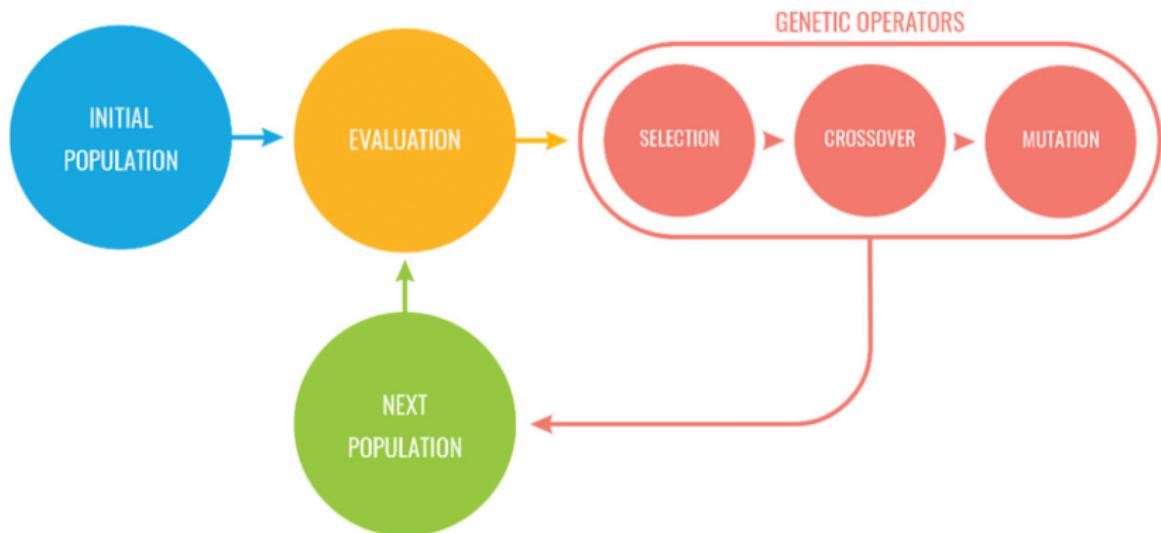
Quantum Kernel

- Tuttavia la scelta del kernel risulta spesso problematica.



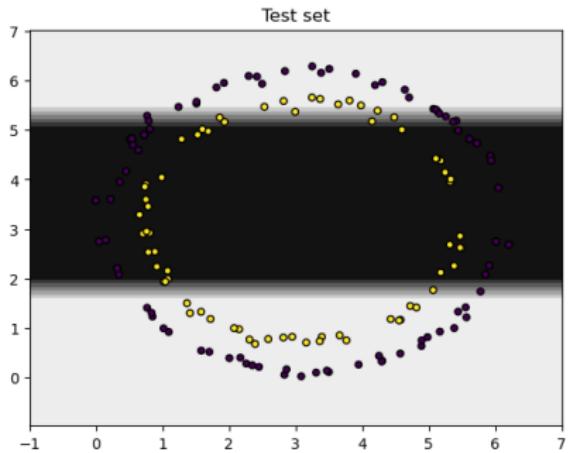
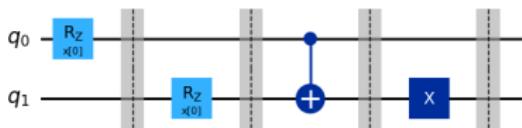
Genetic algorithm

- Un algoritmo genetico può scegliere la miglior feature map.



Genetic algorithm

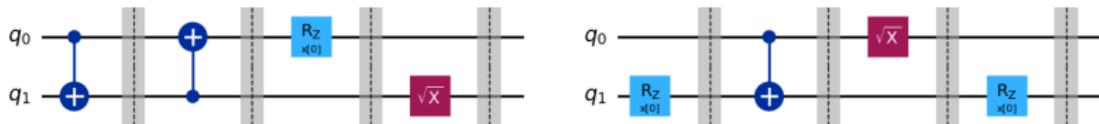
- Gli individui sono formati da gate scelti da un set completo.
- La prima generazione è generata in maniera casuale.



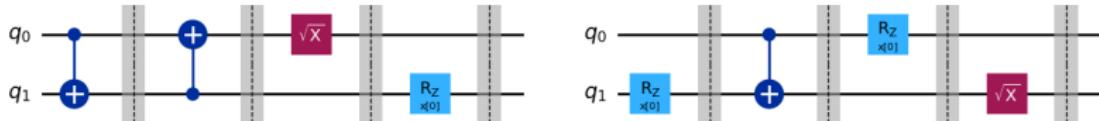
Genetic algorithm

- La fitness di un individuo si calcola a partire dalla sua accuratezza.
- Gli individui sono passati alla seguente generazione con il crossover.

Parent individuals

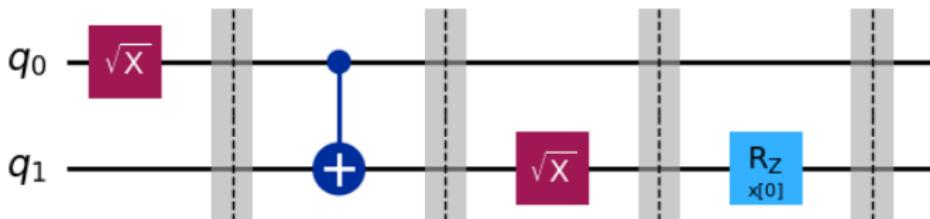
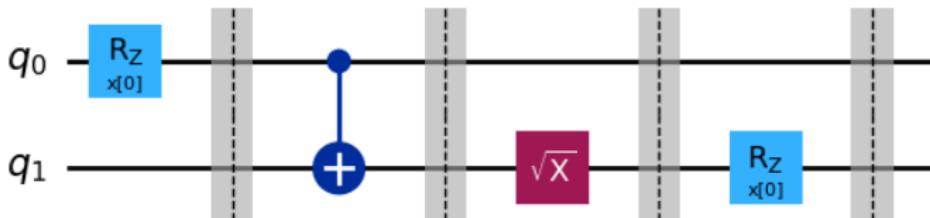


Child individuals



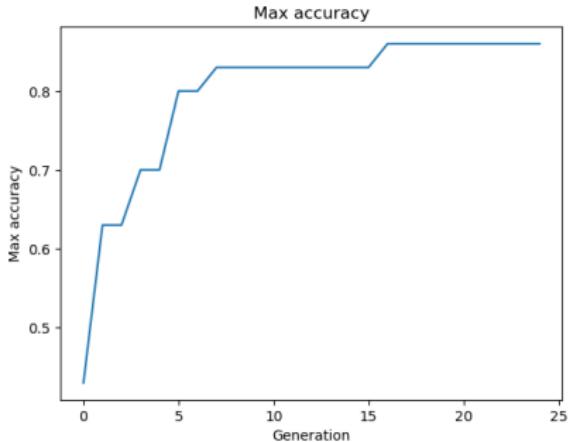
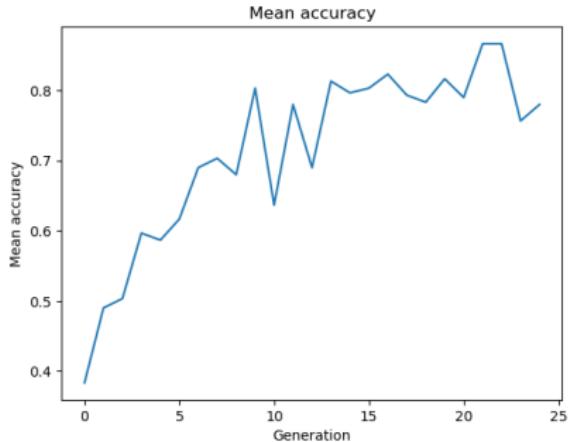
Genetic algorithm

- Inoltre subiscono una mutazione casuale.



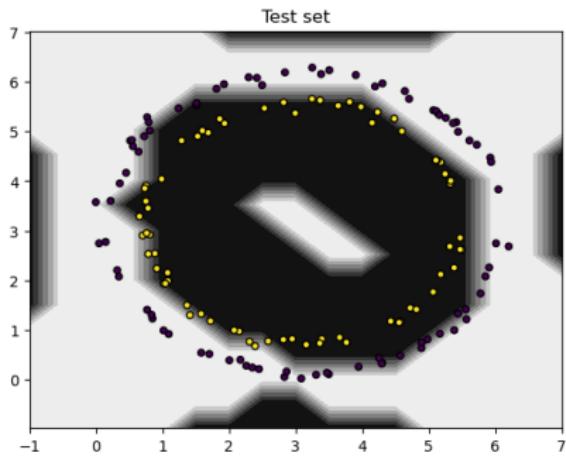
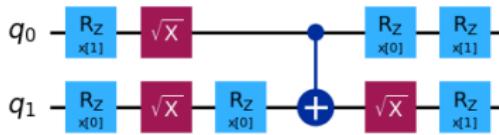
Genetic algorithm

- Con l'andare delle generazioni aumenta l'accuratezza media e quella massima.



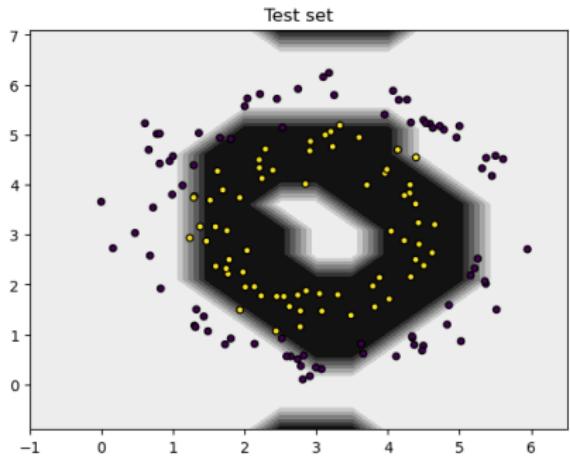
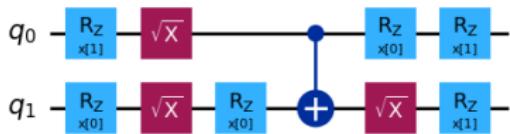
Genetic algorithm

- Otteniamo così un circuito ad alte prestazioni, impossibile da ottenere manualmente.



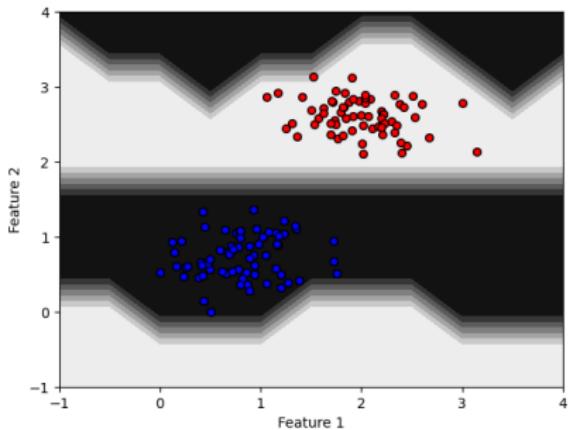
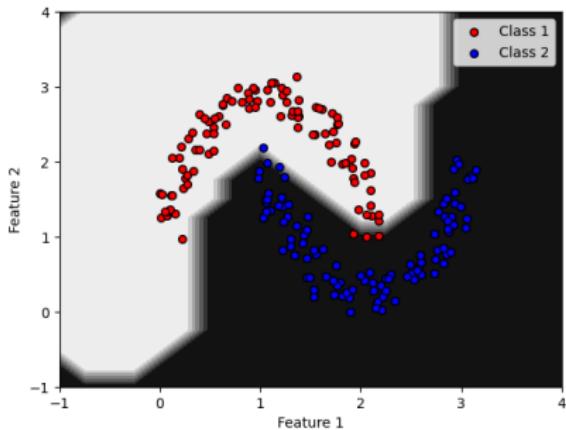
Genetic algorithm

- L'algoritmo si dimostra robusto al rumore e a variazioni della forma dei dati.



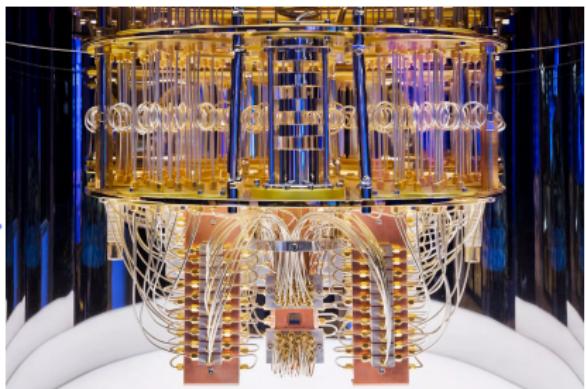
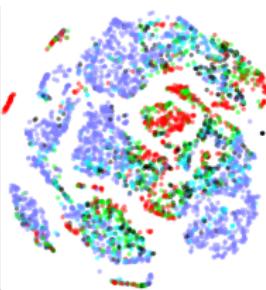
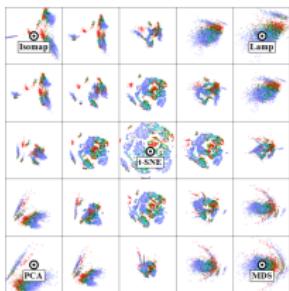
Genetic algorithm

- L'algoritmo si dimostra funzionante su vari tipi di dataset, sia artificiali che reali.



Directions for Future Work?

- L'algoritmo andrebbe ora testato su dataset multidimensionali, e infine su un reale dispositivo quantistico scalabile.



Grazie per l'attenzione!