ARTIFICIAL NEURAL NETWORK-GENETIC ALGORITHM FOR OPTIMIZATION OF MULTIVARIATE FUNCTION: AN APPLICATION TO LACTIC ACID PRODUCTION

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A. Motivation

Maximizing the **Lactic Acid production through machine learning approach.**

- **Traditional Method:**

  Lactic Acid production and its optimal yield depends upon multiple iteration of lab experiments.

- **Artificial Neural Network and Genetic Algorithm:**

  Ability to work with insufficient knowledge.

  Ability to learn by themselves and produce the optimal output.

A. Motivation

Some questions that needed to be explored:

1. Can ANN represent multivariate function?
2. Can the function modeled using Artificial Neural Network (ANN) be optimized by Genetic Algorithm (GA)?
3. Does the obtained maxima coincide with the actual maxima?

B. Procedure

ANN (Artificial Neural Network)

Here,

- b is bias/constant
- w is weight/coefficients
- g is activation function, this adds non linearity
- y_{true} is true value for y
- α is learning rate

Forward Pass

$$f(x) = g(w.x + b)$$

Backward Pass

$$E = ||f(x) - y_{true}||_2^2$$

$$\frac{\delta E}{\delta w} = \frac{\delta E}{\delta f(x)} * \frac{\delta f(x)}{\delta g} * \frac{\delta g}{\delta w}$$

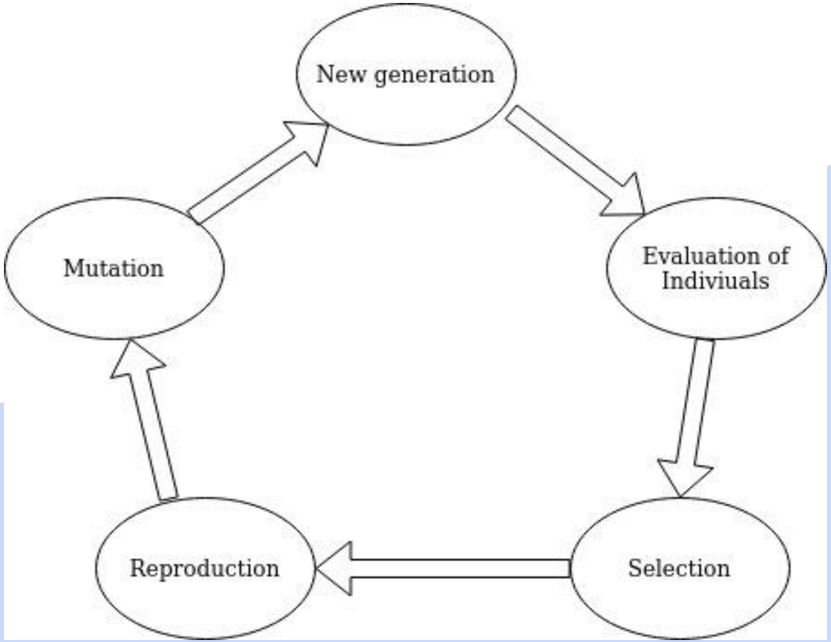
Weight/Coefficients Update

$$W = w - \alpha \frac{\delta E}{\delta w}$$

B. Procedure

Genetics Algorithm (GA)

- One of the Optimization Algorithm
- Inspired from natural selection processes



B. Procedure

Genetics Algorithm (GA)

GA($Fitness$, $Fitness\_threshold$, p, r, m)

Fitness: A function that assigns an evaluation score, given a hypothesis.

$Fitness\_threshold$: A threshold specifying the termination criterion.

p: The number of hypotheses to be included in the population.

r: The fraction of the population to be replaced by Crossover at each step.

m: The mutation rate.

- *Initialize population:* $P \leftarrow$ Generate p hypotheses at random
- *Evaluate:* For each h in P, compute $Fitness(h)$
- While $[\max_h Fitness(h)] < Fitness\_threshold$ do

  Create a new generation, P_S:

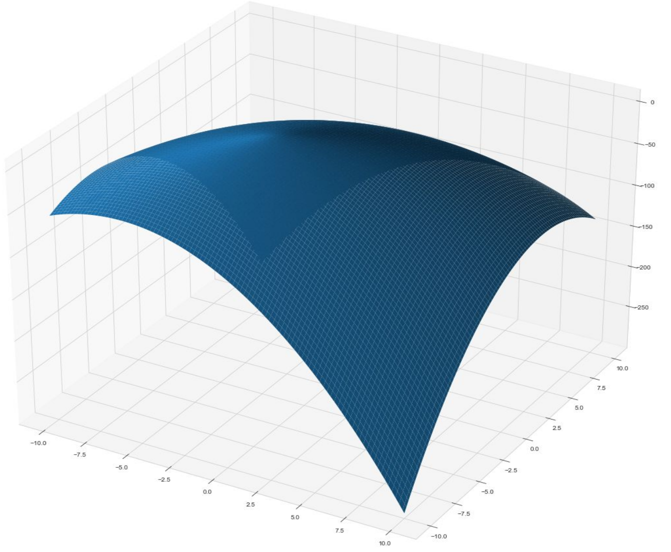
  1. *Select:* Probabilistically select $(1-r)p$ members of P to add to P_S. The probability $\Pr(h_i)$ of selecting hypothesis h_i from P is given by

  $$\Pr(h_i) = \frac{Fitness(h_i)}{\sum_{j=1}^{p} Fitness(h_j)}$$

  2. *Crossover:* Probabilistically select $\frac{r \cdot p}{2}$ pairs of hypotheses from P, according to $\Pr(h_i)$ given above. For each pair, $\langle h_1, h_2 \rangle$, produce two offspring by applying the Crossover operator. Add all offspring to P_s.
  3. *Mutate:* Choose m percent of the members of P_s with uniform probability. For each, invert one randomly selected bit in its representation.
  4. *Update:* $P \leftarrow P_s$.
  5. *Evaluate:* for each h in P, compute $Fitness(h)$
- Return the hypothesis from P that has the highest fitness.

C. Results on Multivariate Function

Equation 1 $$f(x,y) = xy - x^2 - y^2 - 2x - 2y + 4$$



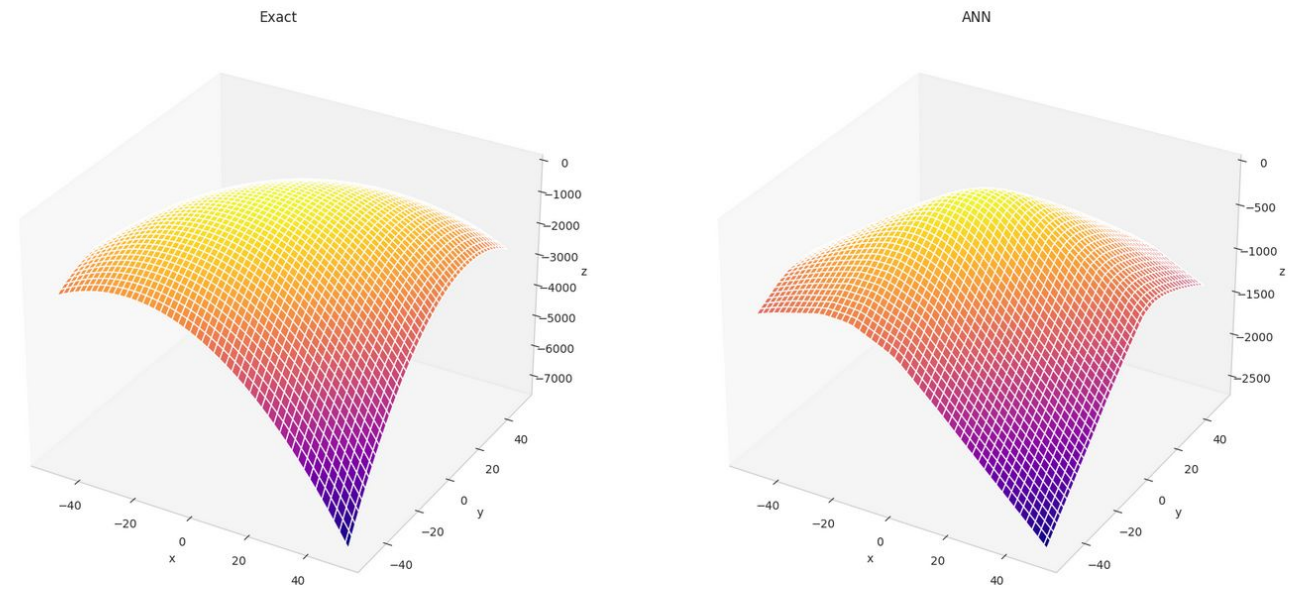
$$f_{max} = 8, (x,y) = (-2,-2)$$

C. Results on Multivariate Function

Equation 1 $f(x, y) = xy - x^2 - y^2 - 2x - 2y + 4$

Root Mean Squared Error = 0.43418562

$$f_{max} = 7.999999$$



$x = -2.000257032654062,$
$y = -2.0011286850112384$

D. Application on Lactic Acid Dataset

About Dataset

Features/Factors

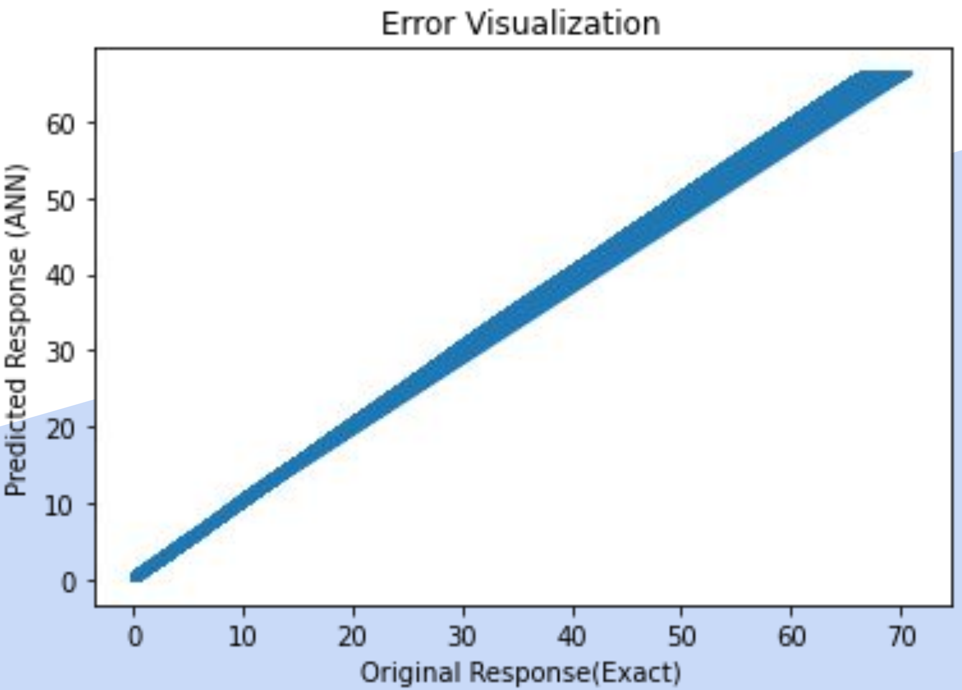
Labels

pH	Temperature	MgSO4	MnSO4	K2HPO4	CaCO3	Tween80	Glycerol	Yeast Extract	(NH4)2SO4	Response
4.0	40.0	0.1	1.0	5.0	4.0	1.0	0.1	1.0	30.0	1.753890
7.0	40.0	1.0	0.1	0.2	4.0	1.0	0.1	10.0	30.0	0.961810
4.0	40.0	1.0	1.0	5.0	0.0	0.1	4.0	10.0	5.0	1.852900
4.0	30.0	1.0	1.0	0.2	4.0	1.0	0.1	1.0	5.0	1.074965
7.0	30.0	0.1	1.0	5.0	0.0	1.0	4.0	1.0	5.0	1.859972

D. Application on Lactic Acid Dataset

Results

	Original Response	Predicted Response
0	0.983000	1.580200
1	1.810470	1.580200
2	1.612447	1.802147
3	1.050000	1.306972
4	3.026800	2.694867
5	3.130000	3.188016
6	2.790000	2.694867



Root mean square error = 0.2717058033029205

D. Application on Lactic Acid Dataset

Results From GA

pH = 5.42
Temperature = 42.90,
$MgSO_4$ = 0.21
$MnSO_4$ = 0.9253484997430782
K_2HPO_4 = 3.3306940025684377,
$CaCO_3$ = 3.896122976285705,
Tween80 = 0.9984142946210325,
Glycerol = 4.740115580208185,
Yeast Extract = 11.463939669976023,
$(NH_4)_2SO_4$ = 16.073667452916382

Final Response = 3.371667

E. Conclusion

- ANN can be used to model a multivariate variable function.
- ANN as the fitness function for our genetic algorithm
- Performing GA we obtain the optimal values for the features that maximizes the ANN.
- ANN + GA processes the pre-existing data of the experiments.
- On our lactic acid optimization problem, the optimal features would translate into the optimal values of the factors needed to yield maximum lactic acid.

F. Future Enhancement

- Comparison with the traditional method.
- The optimized parameters needs to be experimentally verified.

G. References

1. Chapter 3, Artificial Intelligence A Modern Approach, Stuart J. Russell and Peter Norvig, 2022
2. Machine Learning, Tom Mitchell, McGraw Hill, 1997.

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