Blog Entry © Wednesday, May 21, 2025, Backpropagation Artificial Neural Network Experiments by James Pate Williams, Jr.

The first experiment is to learn the following six-input and one-output function:

$$f(\vec{x}) = \sum_{n=1}^{6} x_n^3$$

```
== Menu ==
1 Training (Cubic)
2 Testing (Cubic)
3 Training (BB61)
4 Testing (BB61)
5 Training (Classical Ballistics)
6 Testing (Classical Ballistics)
7 Exit
1
number input units: 6
number hidden units: 24
number output units: 1
number examples: 10
learning rate: 0.05
momentum: 0.01
tolerance: 1.0e-12
number maximum epochs: 20000
PRNG seed: 1
Random Training (Cubic)
1025.91505
2374.49558
571.36680
1063.95325
832.33464
655.94400
2221.58434
1938.22637
3714.14519
927.25822
mse = 0.00000
1025.92114
2374.49873
571.38868
1063.95954
832.32542
655.93037
2221.59473
1938.21475
3714.11729
927.25896
runtime in seconds = 81.00000
```

The second experiment is to find the apex (apogee, summit) of a projectile using the following classical projectile formulas for the time of flight, the horizontal velocity component, the vertical velocity component, the velocity, the x-coordinate, and the y-coordinate:

$$t = \frac{2v_0 \sin\theta_0}{g}$$

$$v_x = v_0 \cos\theta_0$$

$$v_y = v_0 \sin\theta_0 - gt$$

$$x = v_0\, t \cos\theta_0$$

$$y = v_0 t \sin\theta_0 - \frac{1}{2} g t^2$$

These formulas are from the webpage [1]. The back-propagation artificial neural network was translated into C++ from the pseudo-code in the textbook [2].

```
== Menu ==
1 Training (Cubic)
2 Testing (Cubic)
3 Training (BB61)
4 Testing (BB61)
5 Training (Classical Ballistics)
6 Testing (Classical Ballistics)
7 Exit
5
    0
17483
31081
40794
46621
48564
46621
40794
31081
17483
    0
mse = 2.1212100578e-002
    0   1768    1768    2500    0       0       0
11      1768    1414    2264    19426   17483   30765
22      1768    1061    2062    38851   31081   29391
33      1768    707     1904    58277   40794   29432
44      1768    354     1803    77702   46621   46621
55      1768    0       1768    97128   48564   48564
66      1768    -354    1803    116554  46621   43664
77      1768    -707    1904    135979  40794   43774
88      1768    -1061   2062    155405  31081   15066
99      1768    -1414   2264    174830  17483   16388
110     1768    -1768   2500    194256  0       16619
runtime in seconds = 74
```

The columns are the time in seconds, the x-component of the velocity, the y-component of the velocity in feet per second, the x-coordinate, y-coordinate, and the learned y-component

in feet. The height at the apex of the trajectory is accurately learned. The next experiment will be to attempt to learn the battleship USS Iowa (BB-61) class 16-inch 50 caliber projectile motion using the data in the Ordnance Pamphlet 770 [3].

References

[1] "Two-Dimensional Kinematics Projectile Motion," phys.libretexts.org, 21 May 2025. [Online]. Available: https://phys.libretexts.org/Bookshelves/University_Physics/Physics_(Boundless)/3%3A_Two-Dimensional_Kinematics/3.3%3A_Projectile_Motion. [Accessed 21 May 2025].

[2] T. M. Mitchell, "TABLE 4.2 Backpropagation," in *Machine Learning*, Boston, McGraw-Hill Companies, Inc., 1997, p. 98.

[3] B. o. Ordnance, "Ordnance Pamphlet 770," Department of the United States Navy, 1 October 1941. [Online]. Available: https://eugeneleeslover.com/USN-GUNS-AND-RANGE-TABLES/OP-770-1.html. [Accessed 21 May 2025].