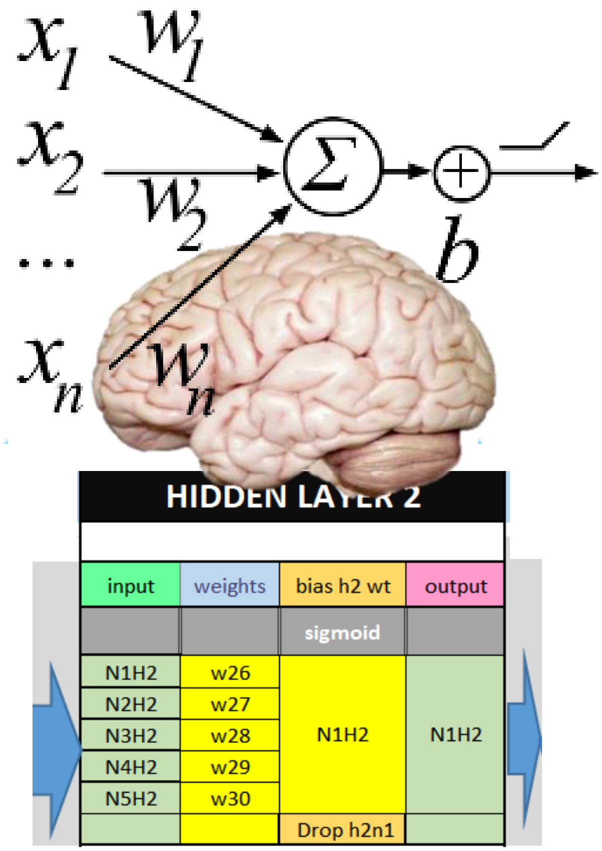

Artificial Neural Network in Machine Learning (ANiMAL)

ANiMAL 20210607v29

A Practical Machine Learning Excel Based Tool
Using a Numeric Variable Data Set
Based on Five Functions of the Human Brain
Targeted at Rural Hand-Pumped Water Wells in Africa

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1. Summary

This document outlines the rationale and mechanisms by which up to five independent numeric variables are analyzed and interpreted using an artificial neural network machine learning tool developed in Microsoft Excel. In addition to the artificial neurons, four other fundamental aspects of the human brain have been successfully mapped into Excel.

A document study of the human brain established its basic structure and functions. It was hoped that lessons could be learnt from the brain's sixty-six million years of development and, in a very very small way, applied to the artificial neural network machine learning tool. The main features of the brain which have substantially influenced the development of the spreadsheet are: the Major Oblongata and the upper brain stem; the cerebellum; cerebrum; corpus callosum; two hemispheres; folding of grey matter and the gyri and sulci.

The result is an intuitive neural network configured as a machine learning tool for practical use. It is currently being applied to data gathered from rural hand pumped water wells in Tanzania. The objective of the implementation is to improve Well uptime and facilitate a proactive approach to local Well maintenance. It is not the intention to make this artificial neural network an answer-generator as this spreadsheet should provide suggestions so it can be regarded as a decision-support-system.

The variables from the Well are numeric and specific to the Well monitoring system used. However, the Machine Learning tool is generic and can be applied to any independent numeric data-set of variables.

The basic Artificial Neural Network in Machine Learning tool (ANiMAL) is being honed and developed further by both the UK and Tanzanian teams.

2. Introduction

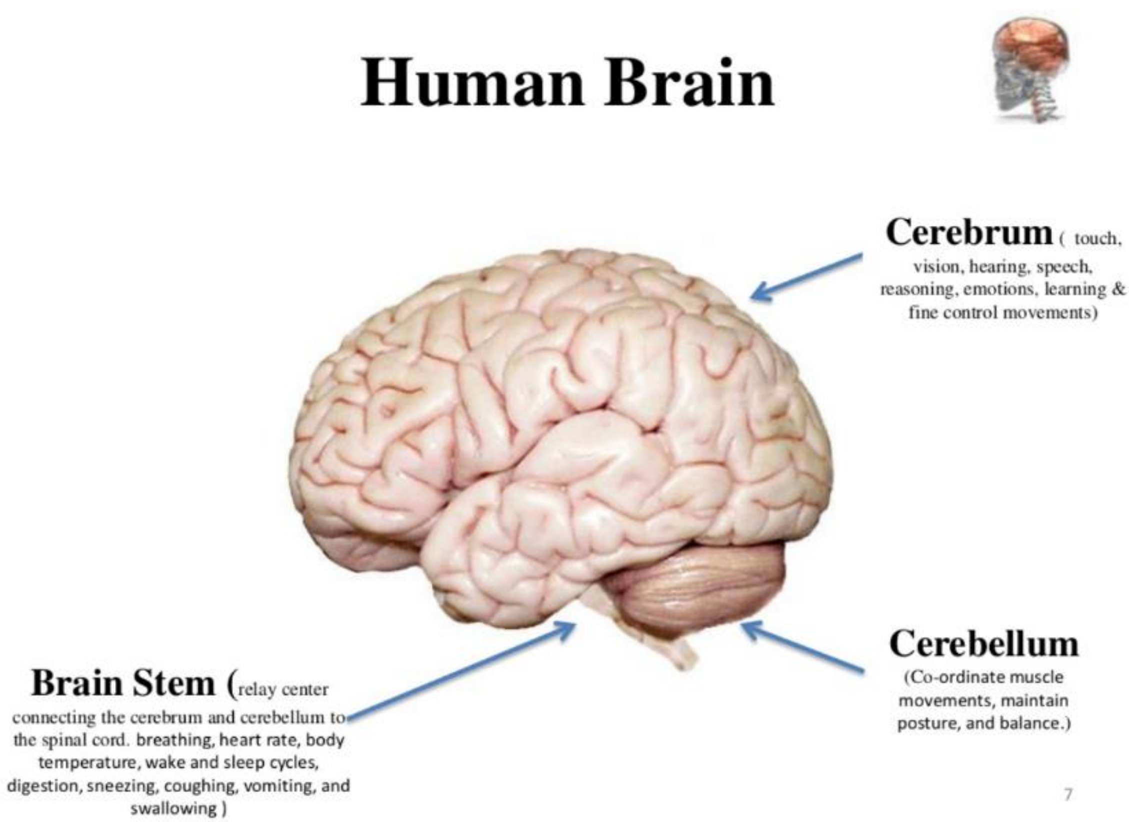
A Well System for On-going Maintenance project (AWSOM) was started mid-2016. The AWSOM monitoring units are designed for rural hand pumped water Wells in Tanzania and are attached to the spout of each Well. The data provided by the AWSOM units are used by the Neural Network Machine Learning tool. The resultant data analysis helps us move away from expensive ambulance-type of Well maintenance and migrate to a more efficient proactive, prioritized targeted maintenance regime. This approach improves both Well uptime and continued water provision.

During the development of the Machine Learning tool, guidance and support was sort from many areas including the mechanical, mathematical and electronic fields but also from the medical profession. Studying the top level functions of the brain have proved beneficial particularly in the partial differential back propagation area of this very basic, easy to use machine learning Excel tool.

The human brain has been reported as containing some 89 billion neurons. This document does not look at ALL the: Who, What, Why, Where, When and How of the human brain. It touches, and only partially, on the What and How. Top level functions are discussed and an attempt made to map the strategic intent of key brain functions to the spreadsheet. It must be remembered that we are not looking at a 1 million times smaller network, or even a 100 million times smaller but a 10 billion times smaller network! With this in mind we are trying to apply lessons learnt from the 66 million year, 89 billion neurons development program of the human brain to about ten artificial neurons.

If we liken each neuron in the human brain to a grain of sand, then we are looking at approximately the size of a road oil tanker full of sand. Using this analogy the size of our machine learning tool equates to about 10 grains of sand.

The machine learning aspects of this project are based on neural network concepts outlined some five decades ago. Over the intervening years there have been extensions to the basic concepts which have made machine learning tools far more effective and practical. In this



project we have tried to learn again from the biology and functions of the brain and walk (crawl?) down the road of Machine Learning and mimic and apply some concepts used into Excel.

The basic structure of the human brain has been reviewed. Structural elements have been adopted by the machine learning tool. In addition to basic functions of the neurons, the concepts behind the: upper brain stem; the cerebellum; the cerebrum and medulla have all been utilized. In addition, recent discoveries of neural dropout and synaptic shrinkage have also been adopted.

However, there are very many areas of the brain that have been excluded. The brain is an enormously complex machine such that the vast majority of systems could not (and probably will never) be mapped across into software and almost certainly not into a spreadsheet.

The '10 grains of sand' neural network combined with the four identified brain systems have resulted in an extremely useful and practical machine learning tool which can perform outstanding feats of analysis and pattern recognition. The authors consider this approach could be the commencement of an exciting journey which can only get more fruitful as time passes.

3. Statement of requirements

The initial requirement and guiding statement in 2016 of the Tanzanian water monitoring system project to which the machine learning tool has been applied was:

" … to be able to fix a water meter on the wells so we can accurately and regularly check on the water being extracted but having that water meter pinging the details back to us running off solar power and also giving its GPS location. I believe some of these are being developed but are expensive and we also need to ensure that the workings are locked in a box for security. Additionally, working in Africa these must be robust with few moving parts that can go wrong and if they do can be easily replaced/fixed…."

These requirements were encapsulated in a collaborative document early the next year (2017). It is these requirements that have been used to develop the well monitoring system.

The electronic unit developed to achieve the above requirements is termed AWSOM (A Well System for Ongoing Maintenance). It produces five data points which are collected on a daily basis from each well. These data points are fed into the Artificial Neural network in Machine Learning (ANiMAL) Excel based tool and guide users to the Wells that are, or are about to be, in trouble and need maintenance support.

The combined statement of requirements of the electronic unit on the Well and the data analysis tool can be summarized as ". . . *to facilitate a self-sustainable water supply through remote hand pumped water wells. The Well monitoring system and associated data analysis is aimed at improving well uptime through prioritized targeted maintenance.*"

ANiMAL is a key component of AWSOM and, although ANiMAL is not essential, it can significantly improve the accuracy of the *'prioritized targeted maintenance schedule improving well uptime'*.

4. The Problem

The problem that the initial AWSOM system faced was in the identification of numerous false positives (calls for maintenance support). For example, when the well monitoring system indicated that the well was not being used, a simple spreadsheet used to flash an alarm saying the well must be broken so a maintenance crew would be tasked to repair it. However other data were not taken into account. Four example, the well would be expected to be used less during the rainy season as rainwater would be harvested and long trips to any water pump were unnecessary.

In addition to rainwater harvesting, if the internal voltage of the unit was low, information may not be sent from the well until the sun charged the unit's internal battery. The low battery voltage could also, incorrectly, indicate low well output. In addition, false positives were occasionally generated when the mobile phone SMS signals faded on some days but indicate twice the amount when SMS was sent (automatically) the next day.

There are a number of scenarios and patterns like this that had to be evaluated. Neural networks are seen as the ideal choice and way forward in this pattern recognition environment. The five numeric variables given by each well provide a simple and increasingly accurate traffic-light output providing effective and efficient use of well maintenance personnel.

5. ANiMAL Overview

The data points provided by the AWSOM units attached to the well spouts include: derived water volume used, the units internal temperature, battery voltage, computer cycle-count and the day-count. The details behind each data point are not relevant to this discussion apart from the fact that the data are all numeric. What is important is that the data are independent variables associated with the running and maintenance of rural Wells in Africa. (Any numeric data set could be analyzed by the ANiMAL tool with equal success.)

So, how can we use Excel for pattern recognition? The first thought was to trawl the internet. This gave many mathematical options, however the thought of emulating aspects of the most successful neural network on the planet (the human brain) was also considered. It is not the intention of this paper to discuss the brain structure or the reasons why many elements of brain structure have been ignored. What is important is to highlight and understand information flow and the strategic intent of each principal area within the brain which can be used in ANiMAL. Even though there are few artificial neurons, the concepts behind ANiMAL have wide applicability and could prove useful in many basic practical pattern recognition fields.

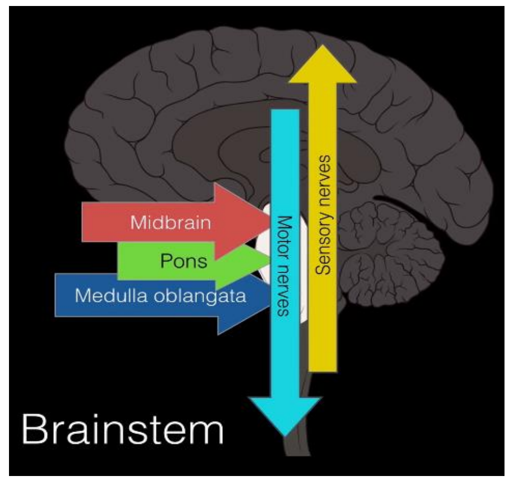
The following sections provide an overview of particular parts of the brain and then outlines how the spreadsheet implementation has been achieved.

6. Switching Routing & Control

6.1. Upper Brain Stem

The brain stem is divided into five parts: the midbrain, the major oblongata, the Varoli's Bridge, and the spinal cord. The function of the brain stem is to receive, process, and adjust certain functions related to attention, vision, sleep, hearing and temperature control etc. Injury to the brain stem is extremely serious since *the brain stem regulates almost all the daily activities of our body*.

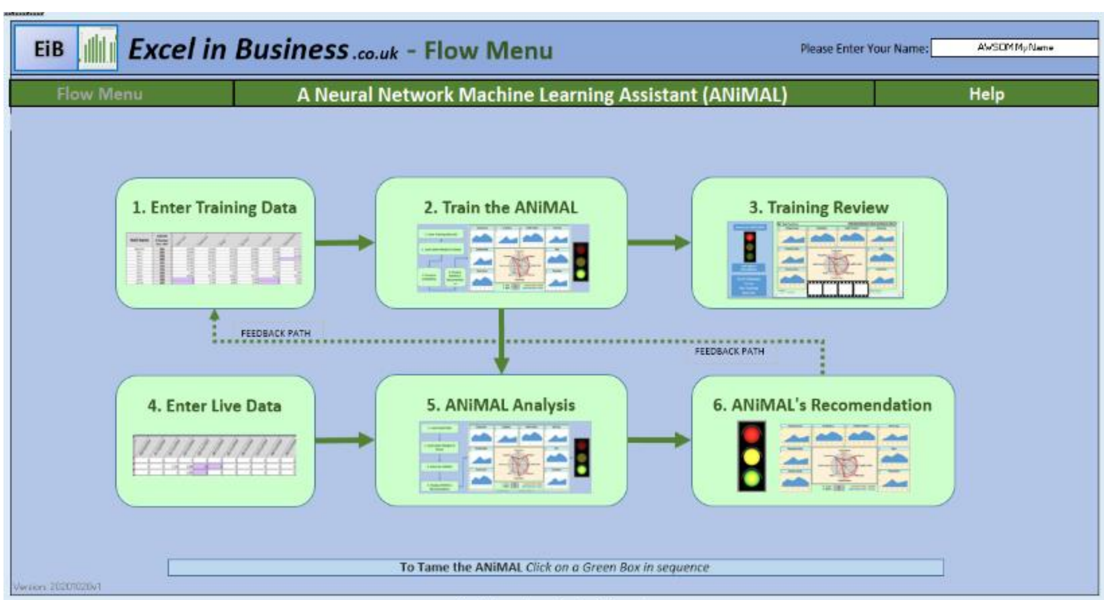
The medulla oblongata is located at the base of the brain. The brainstem connects the brain to our spinal cord. It plays *an essential role in passing messages between our spinal cord and brain*. It is also essential for regulating our cardiovascular and respiratory systems.



6.2. ANiMAL's Flow-Menu

The brain stem controls "*almost all daily activities*", also the Medulla Oblongata is the main *information highway* between the body and the brain.

Similarly, the ANiMAL's ***Flow-Menu*** *controls all activities* within the ANiMAL Excel spreadsheet. The 'point-and-click' Flow-Menu is the main interface and *information highway* between the user and the artificial neural network pathways.



ANiMAL Flow-Menu

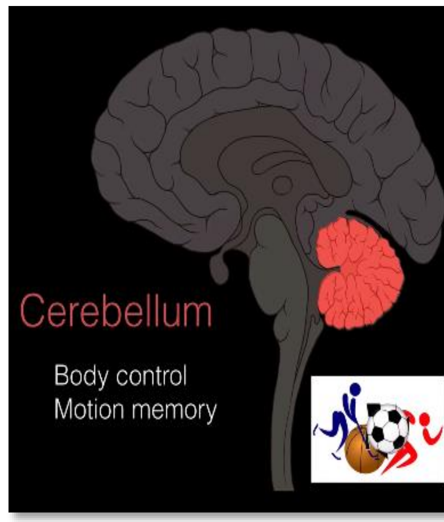
All activities within the neural network and machine learning environment are accessed and controlled through the Flow-Menu. This is a highly intuitive point-and-shoot menu system can be said to reflect *some basic elements* and activities of the medulla oblongata.

7. Automated Functions

7.1. The Cerebellum

Damage to the cerebellum can lead to:

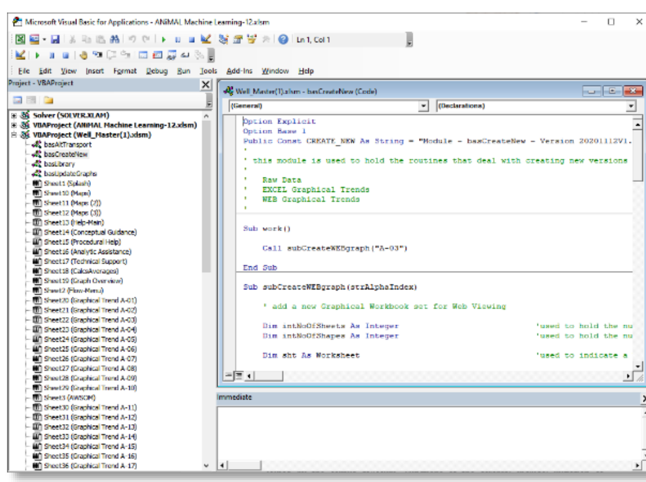
1. Loss of coordination of motor movement (asynergia);
2. The inability to judge distance and when to stop (dysmetria),
3. The inability to perform rapid alternating movements (adiadochokinesia),
4. Movement tremors (intention tremor),
5. Staggering, wide based walking (ataxic gait).



Walking, distance measurement and alternating movement are *learned activities but are performed almost automatically under normal conditions.*

7.2. Excel VB Macros

A similarity can be seen in Excel as Learned Activities in the cerebellum can be mapped to activating Excel's *learned activities within its own VB macros.*

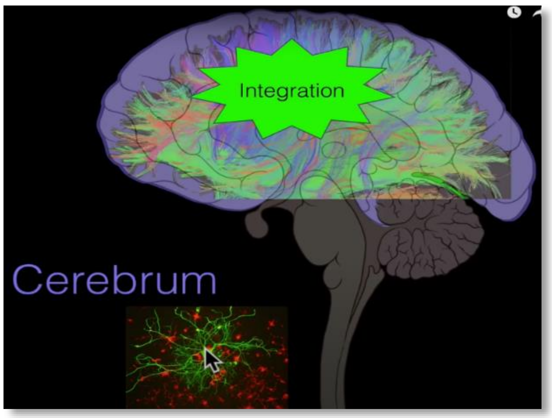


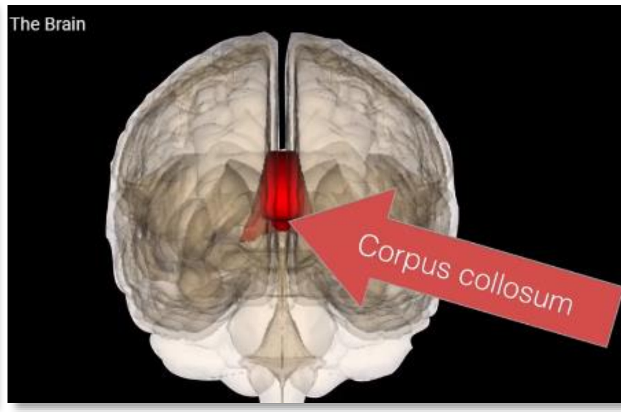
There are many activities under macro control and, as in the cerebellum, damage or corruption of the VB macros can cause significant problems of the spreadsheet's performance.

8. Learning Functions

8.1. The Cerebrum

The cerebral (front of brain) is composed of the right and left hemispheres which are joined by the corpus callosum. Functions of the cerebrum include: initiation of movement, temperature, touch, vision, hearing, judgement, emotions reasoning, *problem solving and learning.*



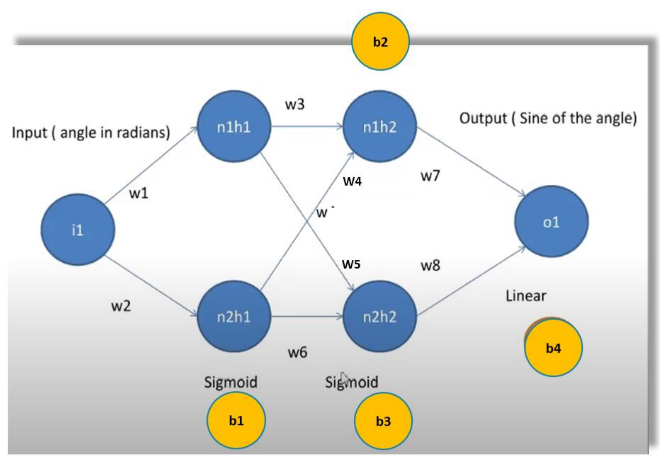


It is in the neurons of the cerebrum where most learning takes place.

8.2. Excel's Artificial Neural Network

Mapping the function of the cerebrum into Excel's neural networks is straightforward. *This is where the main problem solving and learning aspects of the spreadsheet take place*. Artificial Neural Networks are the central focus here.

In addition, in Excel a technique has been adopted to mimic the two hemispheres of the human brain. Although the two hemispheres are not duplicates, their activities are coordinated and regulated by the corpus collosum.



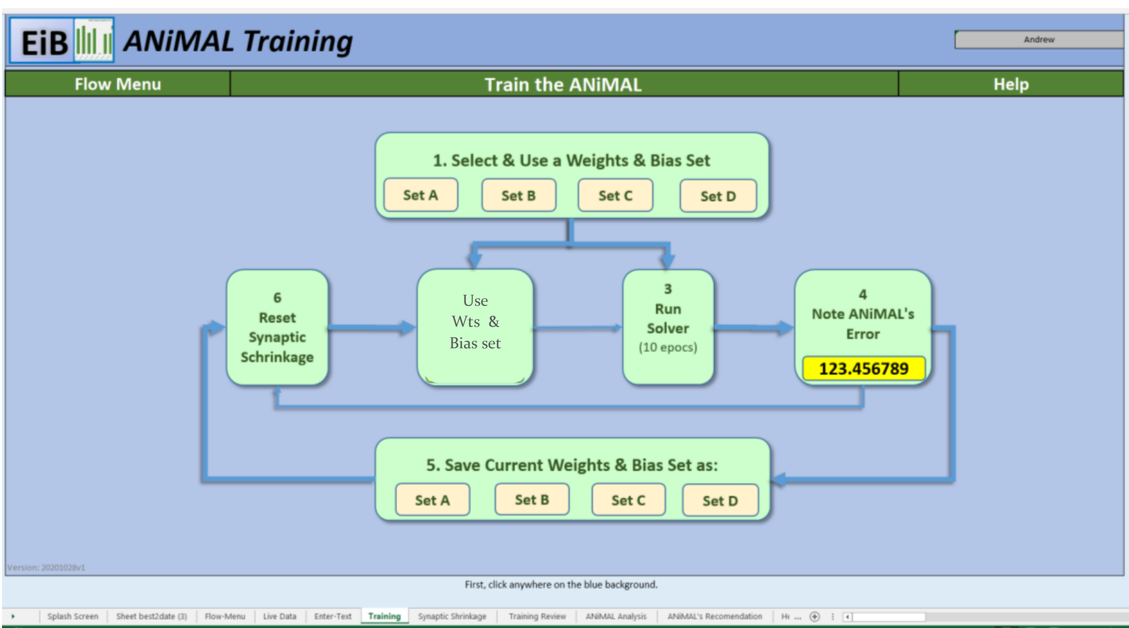
Traditional Neural Network View

A time multiplex version of a single 'hemisphere' (artificial neural network) has been adopted. This time multiplexing can be regarded as using the same neural network more than once on the same problem by using very different starting points. Lessons are learnt at each time-snapshot by the same neurons but with different weights and biases and the best values are selected using the Flow-Menu.

The switching or time multiplexing of a given set of neurons are a poor attempt at mimicking the two hemisphere approach of the brain but the benefits of this approach have proved significant.

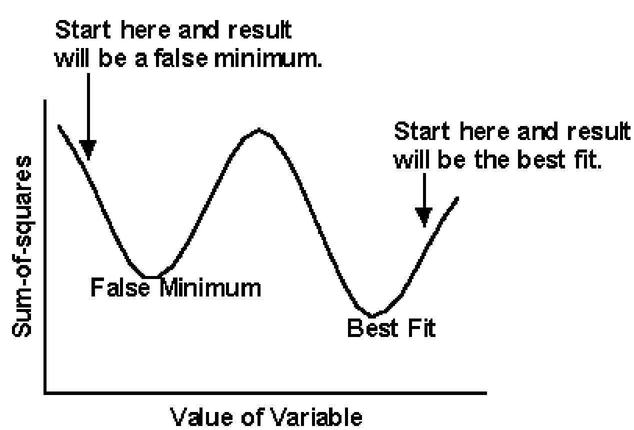
8.3. Set Synaptic Shrinkage

In addition, there is a relatively new function called synaptic shrinkage. Synaptic shrinking within the early brain of humans occurs where learning is most rapid.

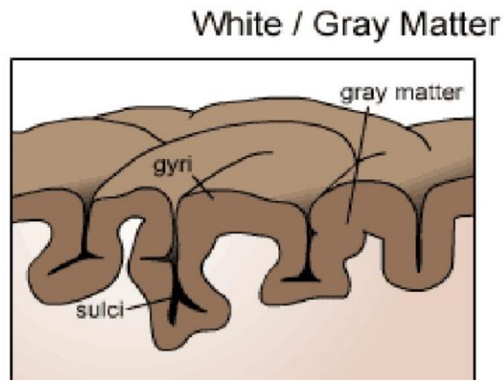


Train the ANiMAL

In Excel, *synaptic shrinking is equivalent to switching off a random set of neurons on demand*. This too has the benefit of jumping out of false minima which the spreadsheet can migrate to in its simplistic back-propagation sequence if not cajoled in this way. Synaptic shrinkage is achieved manually by turning off specific artificial neurons.



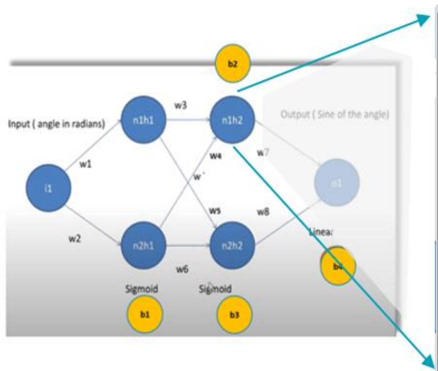
8.4. Surface Area of Cerebrum



Further medical/Excel mapping has been made using the most obvious feature on the surface of each of the brain hemispheres, viz numerous folds. *These folds and the grooves increase the **surface area** of the cerebrum*. The ridges are called gyri, and the grooves are called sulcus. The cerebrum, which looks like a wrinkled mushroom, is positioned over the rest of the brain.

The key point from this aspect of the brain was 'surface area'. In most Excel spreadsheets, artificial neurons and the associated formula are normally compacted into a small a space as possible. Why? Increasing the surface area or the number of spreadsheet cells associated with each artificial neural network can simplify the construction and be beneficially in fault-finding within the machine learning tool.

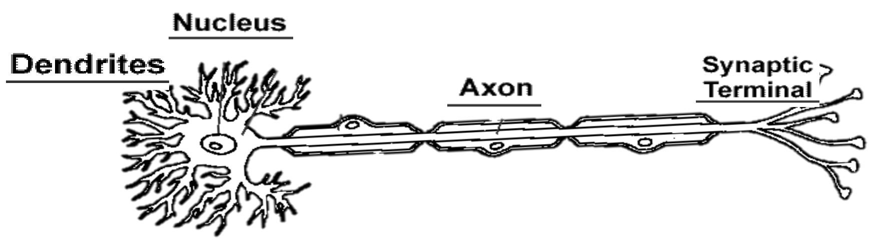
In the traditional neural network machine learning diagrams 'circles' have been used to represent neurons. However, this approach has now evolved and numerous identical blocks of spreadsheet cells are now used. (This has, for obvious reasons, been termed the 'Jig-Saw approach) This makes reading the spreadsheet extremely easy and also aids in the construction of the tool. The construction of the artificial neurons of the spreadsheet becomes like a jig-saw (the child's game). All the pieces are similar and are represented as below:



input	weights	sigmoid	output
0.500	94.9833	0.994362741	0.9943627
0.100	0.0000		
0.500	31.6563		
0.000	0.6110		
0.000	0.7480		
	63.3197760	58.1470718	1
		Bias	Skand

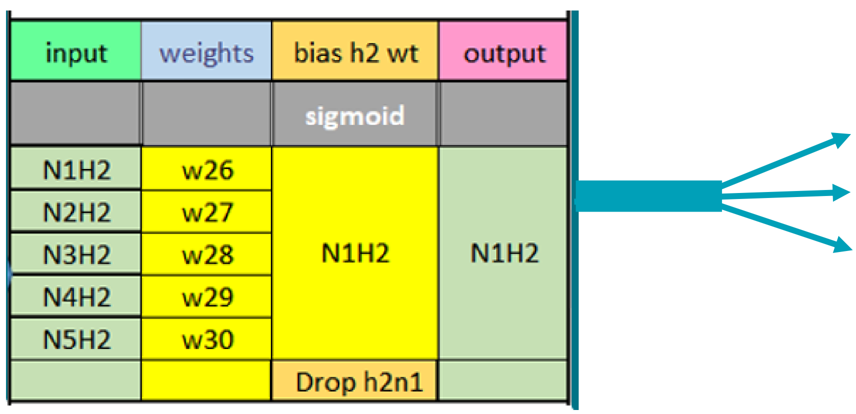
Using a larger surface area (increased real-estate) within the spreadsheet makes sense from a purely visual side too. (It's much easier to review and analyze)

Looking at a representation of a single Neuron we can see the dendrites (inputs) on the left. The nucleus is at the center of the dendrites. The axon then takes the signal and passes it across to the synaptic terminal (outputs) on the right hand side of the below.



Single neuron

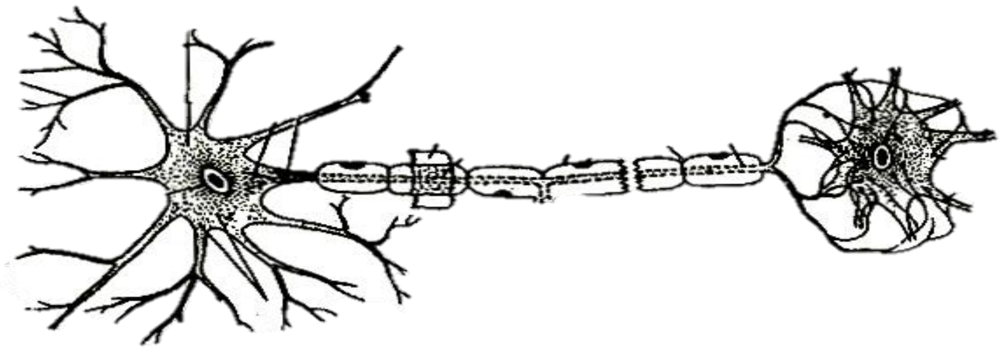
Now let's take one of the artificial neurons in the newly increased surface area format.



Artificial Neuron Jig-Saw Piece

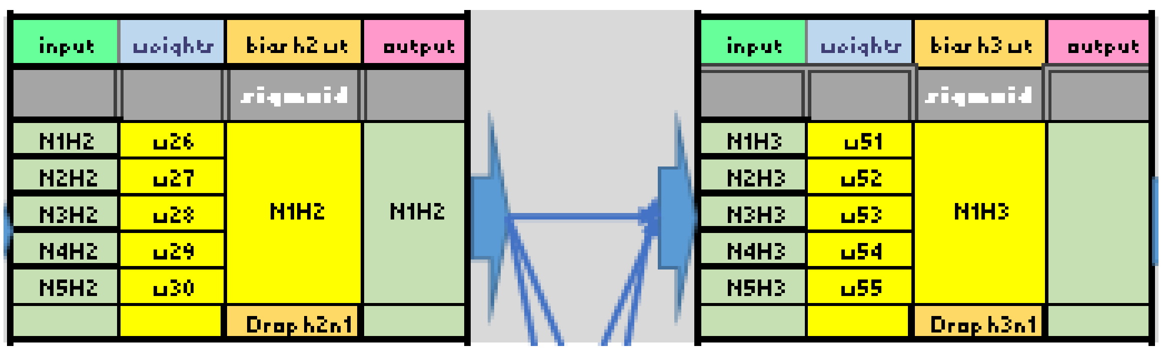
Here the ***inputs*** (dendrites) are on the left (Green -NxH2). The nucleus at the center, Yellow-N1H2. The spreadsheet then takes the signal and passes it to the ***output*** (synaptic terminal) on the right hand side of the above (Green-N1H2) where the 'axon' passes it to the next stage.

Now placing two ***real*** neurons in series we have the synaptic terminal of the neuron on the left feeding the dendrites of the next neuron on the right:



Two real neurons in Series:

Placing two *artificial* neurons in series we have the output or synaptic terminal of the left of the neuron feeding, through the blue lines, the inputs or dendrites of the next neuron on the right hand side of the diagram,



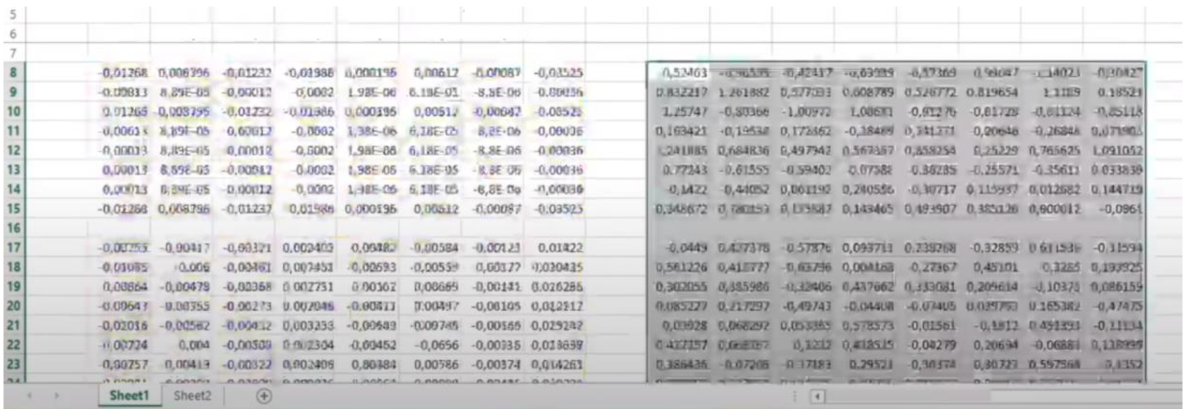
Two artificial neurons in series:

It is interesting to note that in most of the medical texts the dendrites are the inputs to the neurons and the synaptic terminals are the outputs. However in the spreadsheet version there are a number of inputs which simulate the dendrites but there is only one output. This output is carried to the dendrites or inputs of the next artificial neuron via the blue lines in the diagram which are purely linkages and connections in the spreadsheet. So this begs the question, is the synaptic terminal of the real neurons the real outputs or, as in the case of the artificial neuron, just the end of a transmission line?

The next question raised by the artificial neuron is, are all the synaptic terminal outputs in a real neuron the same? Is the signal that travels down the axon into the synaptic terminal modified in any way by: the Schwann cells, the nodes of Ranvier or the synaptic vessels? It is certainly the case that in the *artificial* neuron there is only one output from one neuron, however what lessons can Excel learn by modifying Excel to mimic the multiple synaptic terminal outputs?

This has led to the creation of a new mathematical modifier to the neuron: the Synaptic Shrinkage and Expander (SkXpand) modifier. Although shrinkage occurs in the young whilst learning, and Drop-Out can be a useful learning aid too, a single neuron can have many inputs the next neuron. If all the output dendrites have the same output value, multiple inputs equates to multiplying or expanding the output of that neuron. Both these actions can be achieved through a single spreadsheet cell (SkXpand). This could be a learned parameter but that has not been tested yet.

Below is a typical spreadsheet of a typical neural network. It's compact, efficient, fast but difficult to fault find and hard to see what is happening in the network

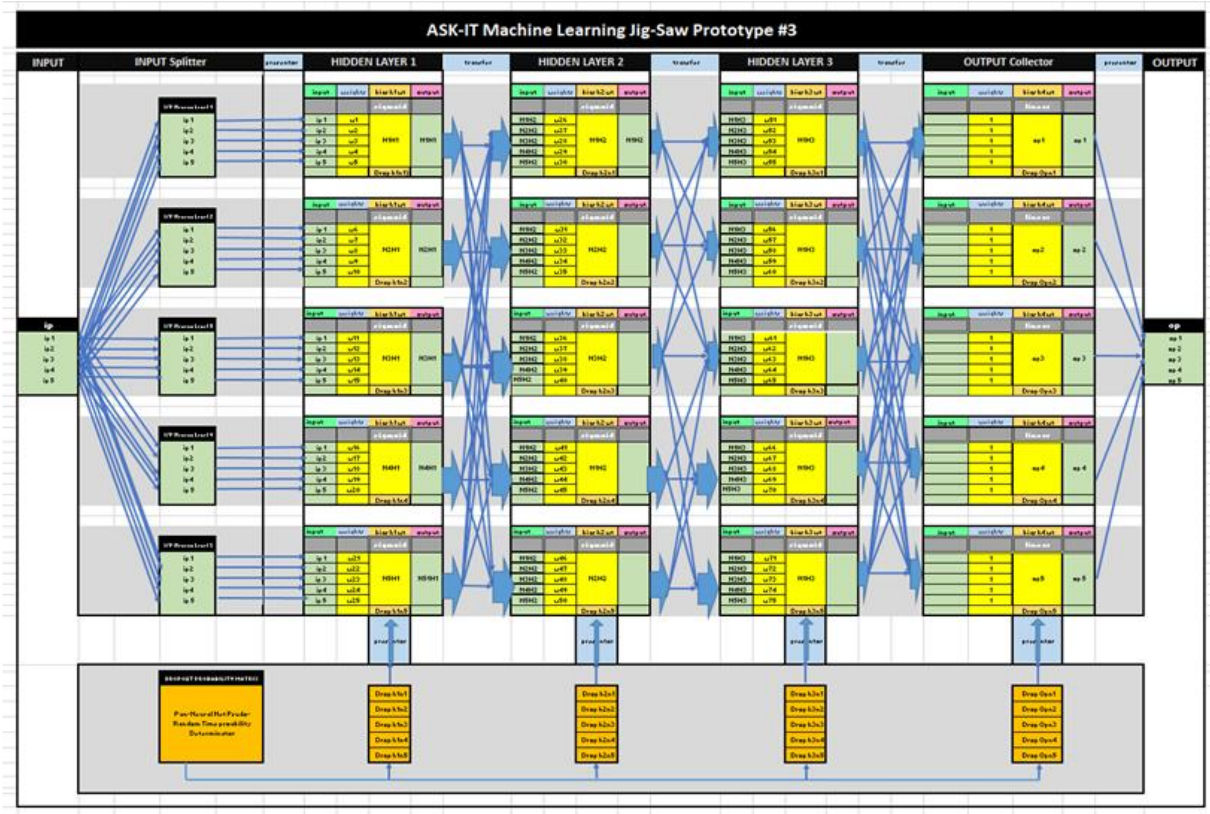


5								
6								
7								
8	-0,01268	0,006396	-0,01232	-0,01988	0,000196	0,00612	-0,00087	-0,03525
9	-0,00013	8,89E-05	-0,00012	-0,0002	1,98E-06	6,18E-05	-8,8E-06	-0,00036
10	0,01268	-0,008796	-0,01232	-0,01986	0,000196	0,00512	-0,00047	-0,03525
11	-0,00013	8,89E-05	0,00012	-0,0002	1,38E-06	6,18E-05	8,8E-06	-0,00036
12	-0,00013	8,89E-05	0,00012	-0,0002	1,98E-08	6,18E-05	-8,8E-06	-0,00036
13	0,00013	8,89E-05	-0,00012	-0,0002	1,98E-06	6,18E-05	-8,8E-06	-0,00036
14	0,00013	8,89E-05	-0,00012	-0,0002	1,98E-06	6,18E-05	-8,8E-06	-0,00036
15	-0,01268	0,008796	-0,01237	0,01986	0,000196	0,00612	-0,00087	-0,03525
16								
17	-0,00255	-0,00417	-0,00321	0,002403	0,00482	-0,00584	-0,00123	0,01422
18	-0,01085	0,006	-0,00461	0,007453	-0,02693	-0,00559	0,00177	0,030435
19	0,00864	-0,00479	-0,00368	0,002751	0,00367	0,00665	-0,00141	0,026285
20	-0,00647	-0,00355	-0,00273	0,002046	-0,00411	0,00497	-0,00105	0,012212
21	-0,02016	-0,00582	-0,00412	0,003253	-0,00683	-0,00745	-0,00566	0,025242
22	-0,00724	0,004	-0,00509	0,002304	-0,00452	-0,0656	-0,00335	0,018697
23	-0,00757	0,00413	-0,00322	0,002409	0,00384	0,00586	-0,00374	0,014263

8	0,52463	[illegible]	-0,42417	-0,63939	-0,57369	[illegible]	-1,14023	-0,30427
9	0,832217	1,261882	0,577033	0,608789	0,526772	0,819654	1,1119	0,18521
10	1,25747	-0,80366	-1,00972	1,08681	-0,91276	-0,81728	-0,81124	-0,85118
11	0,163421	-0,19538	0,172462	-0,18489	0,341271	-0,20646	-0,26846	0,071906
12	1,241885	0,684836	0,497942	0,567357	0,858254	0,25229	0,765625	1,091052
13	0,77243	-0,61555	-0,59402	0,07588	-0,38285	-0,25571	-0,35611	0,033839
14	-0,1422	-0,44052	0,061192	0,240556	-0,30717	0,115937	0,012682	0,144719
15	0,348672	0,780153	0,133887	0,143465	0,493907	0,385126	0,600012	-0,0961
16								
17	-0,0449	0,427378	-0,57876	0,093711	0,238268	-0,32859	0,611536	-0,11594
18	0,561226	0,418777	-0,63796	0,004168	-0,27367	0,45101	0,3285	0,193925
19	0,302055	0,385986	-0,32406	0,437662	0,333081	0,209614	-0,10373	0,086159
20	0,085227	0,217297	-0,49743	-0,04408	-0,07405	0,039793	0,165382	-0,47475
21	0,03928	0,068292	0,053365	0,578573	-0,01561	-0,1812	0,491391	-0,11134
22	0,427157	0,668067	0,1212	0,418515	-0,04279	0,20694	-0,06881	0,118999
23	0,386436	-0,07208	-0,17183	0,29521	-0,30374	0,30723	0,557568	0,1352

Sheet1 Sheet2

The jigsaw version (ANiMAL) on the other hand (as below) is much larger, is less efficient but its operation is self-evident. The full repetitive, jigsaw like structure of the artificial neural network of the spreadsheet now looks as below: (The ANiMAL Jigsaw)



The ANiMAL Jigsaw Spreadsheet Structure

9. ANiMAL Description

The ANiMAL Excel tool lists six activities all of which are encompassed by the Flow Menu, Viz:

1. Enter Training Data
2. Train the ANiMAL
3. Training Review
4. Enter Live Data
5. ANiMAL Analysis
6. ANiMAL's Recommendation

Each are outlined below.

9.1. Enter Training Data

There are two sets of data that have to be entered, first the training data and secondly the live data. Training data entry is normally the majority of the data entry work. The second data entry task is the live data coming from, in this case, the hand pumped water wells.
Data entry into the spreadsheet is accomplished by simply entering the data into each cell as required (in typical Excel fashion). This can be achieved by using the normal csv format or manually through a table as below.

The live data normally enters one row at a time whereas the training data can be very large in comparison. This ANiMAL tool only permits a limited set of training data to be entered. All the training cells must contain relevant data. (Even if some of the data is repeated. There can be no blanks – try it and see how the results change.)

EiB **ANiMAL** (Artificial Neural Network in Machine Learning)

Flow Menu | Help | **Enter Training Data**

Version: 20201028v1 13/11/2020

Enter TEXT

Then click ***File*** & ***Save***

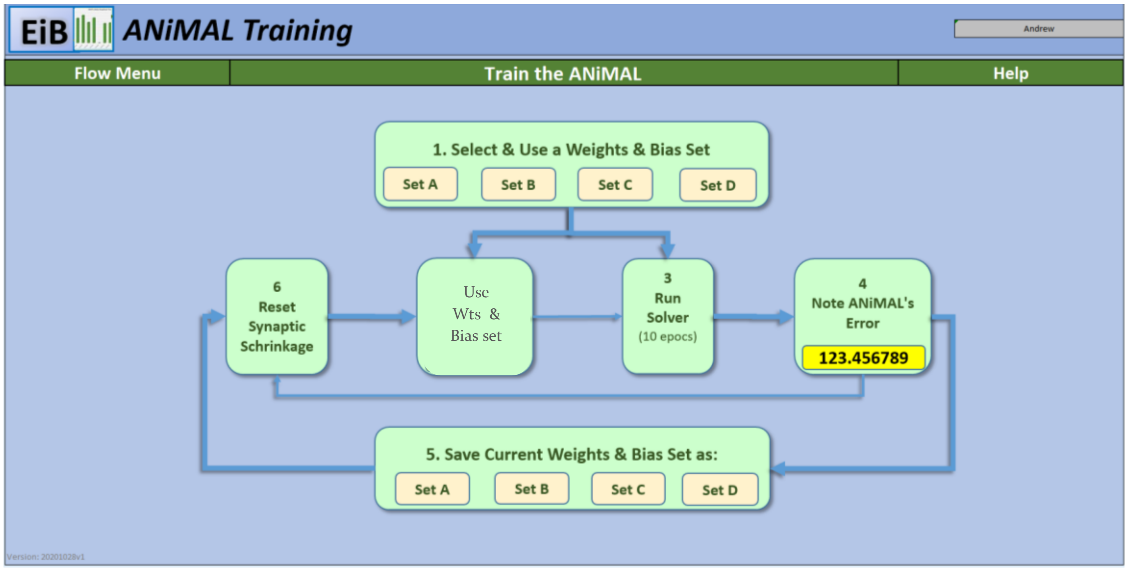
Well Number	Date	Temperature	Voltage	Pump Count	Work Day	Powered Time	Pump Count # 2	Rain Yes=1	Answer
3889	11/11/2020	46.0	4.80	50,000	66	1,662	36,087	0	**2**
3889	10/11/2020	50.0	4.89	50,090	67	1,621	23,103	0	**1**
3889	09/11/2020	39.0	5.10	48,677	68	1,810	48,877	1	**3**
3889	08/11/2020	27.0	5.01	49,590	69	1,090	14,543		**3**
3889	07/11/2020	46.0	5.16	49,980	70	1,376	49,339		**3**
3889	06/11/2020	37.0	5.24	15,000	71	1,440	3,768		**2**
3889	05/11/2020	45.0	5.33	50,748	72	1,368	18,448		**2**
3889	04/11/2020	26.0	5.41	200	73	1,204	27,325	1	**1**
3889	03/11/2020	49.0	5.50	43,750	74	1,280	20,758		**3**
3889	02/11/2021	28.0	5.58	32,806	33	1,337	28,246		**1**
3889	01/11/2021	49.0	5.66	11,358	34	1,724	12,265		**2**
3889	31/10/2021	42.0	5.66	42,287	35	1,022	4,291		**1**
3889	30/10/2021	40.0	4.89	44,221	36	1,827	38,836	1	**3**
3889	29/10/2021	42.0	5.10	45,300	37	1,305	48,562		**2**
3889	28/10/2021	36.0	5.01	4,000	38	1,068	47,561		**1**
3889	31/10/2021	28.0	5.16	16,624	39	1,230	54,566		**1**
3889	30/10/2021	48.0	5.41	11,112	0	1,654	36,133		**1**
3889	29/10/2021	38.0	5.50	21,728	41	1,043	48,403		**1**
3889	28/10/2021	46.0	5.58	18,461	0	1,368	38,996		**1**
3889	31/10/2021	31.0	4.89	50,521	43	1,937	42,854	1	**1**
3889	30/10/2021	27.0	5.10	5,120	44	1,126	21,636		**1**
3889	29/10/2021	34.0	5.01	2,161	0	1,124	12,997		**1**
3889	28/10/2021	47.0	5.16	28,501	46	1,246	54,490		**1**
3889	31/10/2021	28.0	5.24	33,257	0	1,419	30,210		**1**
3889	30/10/2021	49.0	5.33	26,213	0	1,485	30,334		**1**
3889	29/10/2021	27.0	5.41	44,157	49	1,751	23,540		**1**
3889	28/10/2021	49.0	5.50	15,894	50	1,851	6,367		**1**

Training Data Entry Screen

9.2. Train the ANiMAL

After training data entry into the spreadsheet, ANiMAL training can commence. There are six basic steps necessary to train and run the ANiMAL:

1. Select and Use a Weights-and-Bias Set
2. Run with a weights and biases of random probability
3. Run solver (100 Epochs)
4. Display ANiMAL Error
5. Save Current Weights and Biases set (A,B or C)
6. Reset Synaptic Shrinkage/Expansion manually



Train the ANiMAL Excel Screen

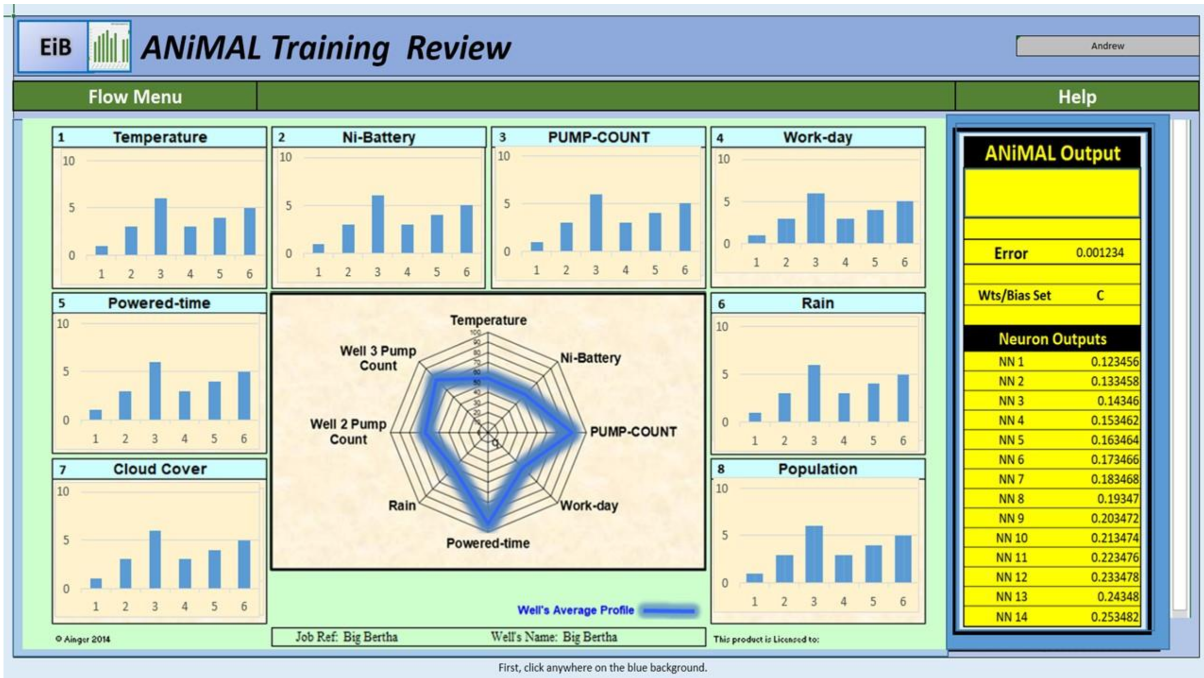
This diagram can be walked-through in almost any sequence required. You'll soon get to know after use how the mechanisms work and how to ensure that the new ANiMAL's error is as low as possible. (However the recommended sequence initially is item 1, then item 3 and run the solver, then after viewing item for running (press three again to see if the error reduces) then click on item 5, (Set A.) The aim here is to minimize the error in box 6.

If after running item 3, the solver, the error refuses to be satisfactorily low then box 6 should be investigated and the system tried again. If the error is still high then click on Box 2 and reset the weights and biases to a random probability and start again. This is a manual circuit to go round the loop. It is found beneficial to do this at least three times saving, in item 5, the best configuration of weights and biases.

In the introduction it was stated that the ANiMAL neural network tool is not an answer-generator but a suggestion-maker. It can be seen that the interactive nature of the training mechanism and levels of human input promote an almost symbiotic relationship between the artificial neural network machine learning spreadsheet tool and the User. ANiMAL can be seen as a true decision support system can be used successfully in many environments.

9.3. Training Review

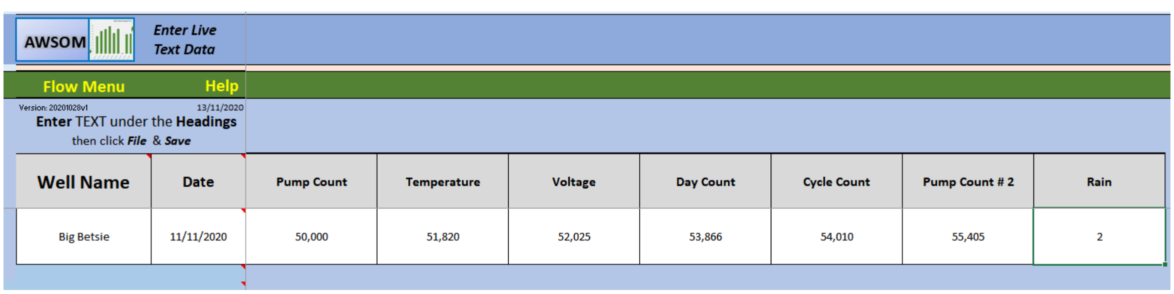
After training the ANiMAL through the Training Menu (Box 2 of the Flow-Menu) The Training Review screen can be viewed. This provides a diagrammatic representation of both the traditional Excel view together with the ANiMAL's view.



The central thick blue spider/radar chart indicates the average value of the data concerned. The thickness of the line representing an approximate standard deviation value. The yellow table on the right shows the ANiMAL neuron outputs and the value of the current error.

9.4. Enter Live Data

Entering a live data is relatively straightforward as it only involves one line of data. This is accessed through box 4 on the Flow-Menu. The headings for the data are pre-populated as they were identified in the training data set.

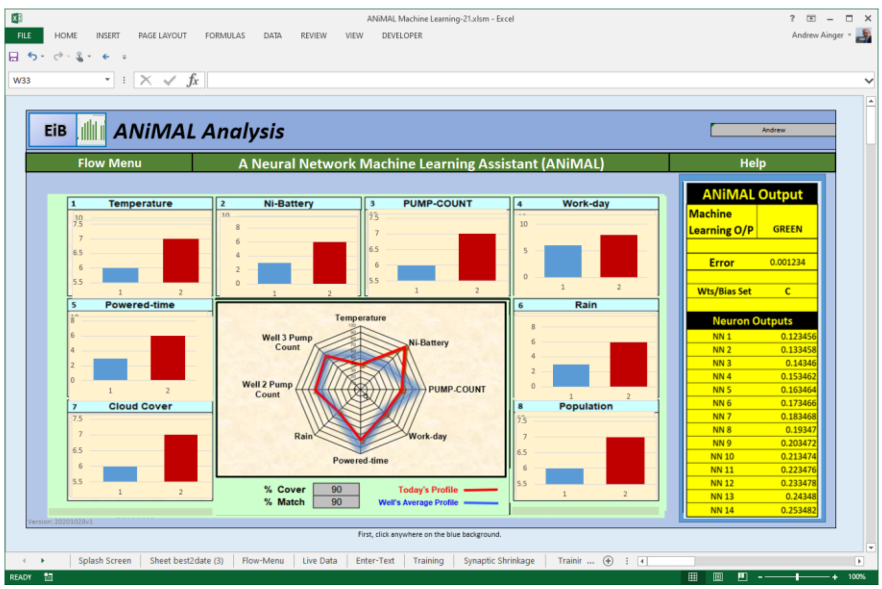


After entering the live data and hitting the return button on the last piece of data the ANiMAL will run its analysis using a weights and biases already set in box two, the training stage. At this stage it will be possible to review item 5 the animal analysis.

9.5. ANiMAL Analysis

The ANiMAL analysis shows not only the neural network outputs but also the Excel spreadsheet outputs. The Excel spreadsheet outputs are the histograms and the spider or radar chart in the centre of the histograms. Here the live training data, in red, is overlaid on top of the blue training data radar chart. This makes it obvious whether numerical values differ the most. The histograms must be treated with caution as the blue columns are the average of all the training data in that particular field whereas the red columns indicate the data on one live data set.

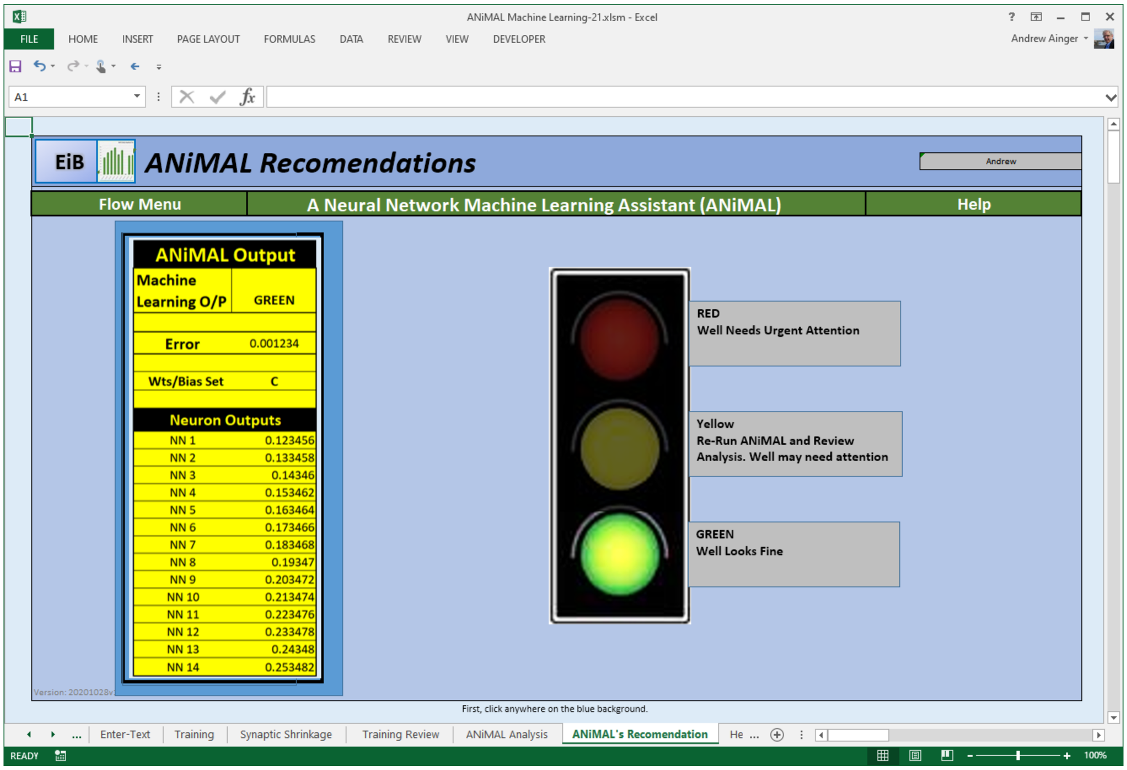
The neural network output is shown in yellow on the right-hand side. In the yellow box the output of each neuron is shown as is the Weights and Bias set selected for this particular analysis run and the error encountered. The main output figure, in this case the traffic-like red amber green signal is shown in the top right-hand corner and is the resultant output of the neural network.



ANiMAL Analysis Screen Shot

9.6. ANiMAL's Recommendations

From the flow menu if box 6, animal's recommendations, is selected then we will get the traffic light summary below. In addition to the red yellow green indicator, in this case indicating the performance of the well and whether maintenance is required, the ANiMAL's neural network outputs are also displayed. The total error is also shown which gives the confidence level of the ANiMAL's neural output.



ANiMAL Traffic Light Summary

10.Conclusions

To conclude the brain is really complex! Trying to compare an Excel spreadsheet with the brain is analogous to a 60,000 mile journey. Here the brain represents the 60,000 miles whilst the Excel spreadsheet represents the first 1 mm of that journey!

However in summary the key areas of the brain whose strategic intent have been adopted and adapted for use in Excel are the:

1. Major Oblongata and the upper brain stem; (in the form of the Flow Menu)
2. Cerebellum; (automation in the form of Visual Basic macros)
3. Cerebrum; (the artificial neural network)
4. Two hemispheres and the Corpus callosum; (time multiplexing of the artificial neurons)
5. Folding of grey matter and the gyri and sulci. (Increased real estate spreadsheet cells)
6. Synaptic shrinkage/expansion. (switching of artificial neurons)

The resultant artificial neural network tool is just that, a tool. It is not a solution generator but a suggestion maker. Through extended use of this easy-to-use Excel spreadsheet it is possible to gain a deeper understanding of the data which helps users predict maintenance issues more successfully and accurately, and in this particular application, keeps the water flowing, in Tanzania.

11. Post Document Note

During ANiMAL testing and evaluation it was found that, given specific inputs, the 10 artificial neurons 'behaved' in a strange manner. No matter what weights or biases were used occasionally the network error signal refused to go below a relatively high value. Even using synaptic shrinkage (drop-out) the error value appeared stubbornly high. It was obviously finding a minima of sorts but not the optimum minima. This gave the impression of almost child-like behavior and was initially disconcerting. However, by judicious use of the SkXpand multiplier an improved minimum could generally be found.

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12. Document Compliance

This document complies with document services library and conforms to BTecNet(UK) standards.

Document Title, Version & Change control:

Ref No.	Title	Author	Comments	Date
#1	Artificial Neural Network in Machine Learning ANiMAL	Andrew WS Ainger	Draft for comments.	11/12/2020
#2	Artificial Neural Network in Machine Learning ANiMAL	Andrew WS Ainger	Draft, corrections with synaptic shrinkage added	28/04/2021
#3	Artificial Neural Network in Machine Learning ANiMAL	Andrew WS Ainger	Jigsaw diagram updated.Highlights added.	7/6/2021