

Guide to Using

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# NeuralTools

*Neural Network Add-In for  
Microsoft® Excel*

**Version 5.7  
September, 2010**

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# Welcome to NeuralTools for Excel

## Welcome

NeuralTools gives Microsoft Excel - the industry-standard data analysis and modeling tool - a new, powerful modeling toolset! NeuralTools is a Microsoft Excel neural networks add-in, allowing you to analyze data in Excel worksheets and work in the familiar Microsoft Office environment. By combining a powerful data manager, along with state-of-the-art neural networks algorithms, NeuralTools brings you the best of two worlds: Microsoft Office ease-of-use and reporting, with robust, accurate predictions from neural networks.

### Work Where You're Comfortable

If you know Excel, you'll know NeuralTools! NeuralTools works just as Excel does, with toolbars, menus and custom worksheet functions, all inside of Excel. Unlike stand-alone neural networks software, there's no steep learning curve and upfront training costs with NeuralTools, because you work just as you are used to working in Excel. Your data and variables are in Excel spreadsheets. You can utilize standard Excel formulas for calculations, along with Excel sorting and pivot tables. Reports and charts from your analyses are in standard Excel format and can utilize all of Excel's built-in formatting capabilities.

## NeuralTools Analyses

Neural Networks are capable of learning complex relationships in data. By mimicking the functions of the brain, they can discern patterns in data, and then extrapolate predictions when given new data. The problems Neural Networks are used for can be divided in two general groups:

- **Classification Problems:** Problems in which you are trying to determine what type of category an unknown item falls into. Examples include medical diagnoses and prediction of credit repayment ability.
- **Numeric Problems:** Situations where you need to predict a specific numeric outcome. Examples include stock price forecasting and predicting the level of sales during a future time period.

Neural Networks are used in a broad range of applications including: stock market prediction, credit and loan risk assignment, credit fraud detection, forecasting sales, general business forecasting, investment risk, medical diagnosis, research in scientific fields, and control systems.

NeuralTools includes the latest neural network algorithms to make the best predictions on both classification problems (called category prediction in NeuralTools) and numeric problems.

## NeuralTools Data Management

NeuralTools provides a comprehensive dataset and variable manager right in Excel, similar to that provided with StatTools, Palisade's statistics add-in for Excel. You can define any number of datasets, each with the variables you want to analyze, directly from your data in Excel. NeuralTools intelligently assesses your blocks of data, suggesting variable names and types as well as data locations. Your datasets and variables can reside in different workbooks and worksheets, allowing you to organize your data as you see fit. Then, you train neural networks that refer to your variables, instead of re-selecting your data over and over again in Excel. And NeuralTools' variables aren't limited in size to a single column of data in an Excel worksheet – you can use the same column across up to 255 worksheets for a single variable!

## NeuralTools Reporting

Excel is great for reports and graphs, and NeuralTools makes the most of this. NeuralTools uses Excel-format graphs, which can be easily customized for new colors, fonts and added text. Report titles, number formats and text can be changed just as in any standard Excel worksheet. Drag and drop tables and charts from NeuralTools reports straight into your own documents in other applications.

NeuralTools Industrial also includes Live Prediction, where predicted values are calculated as new data is entered into your Excel worksheet. This live calculation happens automatically, just like other Excel recalculations.

## Data Access and Sharing

Excel has great data import features, so bringing your existing data into NeuralTools is easy! Use standard Excel capabilities to read in data from Microsoft SQL Server, Oracle, Microsoft Access, or any other ODBC compliant database. Load data from text files or other applications – if you can read it into Excel, you can use it with NeuralTools!

NeuralTools saves all its results and data in Excel workbooks. Just like any other Excel file, you can send your NeuralTools results and networks to colleagues anywhere. Sharing couldn't be easier!

## NeuralTools Professional and Industrial Versions

NeuralTools is available in two versions – Professional and Industrial. The differences are as follows:

- Datasets in NeuralTools Professional are limited to 1000 cases, while NeuralTools Industrial supports datasets with up to 16,777,216 cases.
- Live Prediction, where predicted values are calculated as new data is entered into your Excel worksheet, is provided in NeuralTools Industrial only. This live calculation happens automatically, just like other Excel recalculations.



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# Table of Contents

<b>Chapter 1: Getting Started</b>	<b>1</b>
<b>Introduction</b> .....	<b>3</b>
Checking Your Package .....	3
What the Package Includes.....	3
About This Version .....	3
Working with your Operating Environment .....	4
If You Need Help .....	4
NeuralTools System Requirements.....	6
<b>Installation Instructions</b> .....	<b>7</b>
General Installation Instructions .....	7
Setting Up the NeuralTools Icons or Shortcuts.....	8
The DecisionTools Suite.....	9
<b>Software Activation</b> .....	<b>11</b>
<b>Chapter 2: An Overview of NeuralTools</b>	<b>15</b>
<b>Overview</b> .....	<b>17</b>
Why Neural Networks?.....	17
NeuralTools and Neural Networks .....	18
NeuralTools Menu and Toolbar.....	19
Data Sets and the Data Set Manager .....	19
Training a Neural Network.....	21
Testing a Network.....	26
Prediction.....	27
NeuralTools Reports and Charts.....	29
NeuralTools Utilities .....	29
Using NeuralTools with StatTools, Solver and Evolver .....	30
<b>Chapter 3: NeuralTools Reference Guide</b>	<b>31</b>
<b>Introduction</b> .....	<b>33</b>
<b>Reference: NeuralTools Icons</b>	<b>35</b>
<b>NeuralTools Toolbar</b> .....	<b>35</b>

<b>Reference: NeuralTools Menu Commands</b>	<b>37</b>
<b>Introduction</b> .....	<b>37</b>
Icons in Dialog Boxes .....	38
<b>Command Reference</b> .....	<b>39</b>
Data Set Manager Command .....	39
Train Command.....	44
Test Command.....	56
Predict Command.....	64
<b>Utilities</b> .....	<b>69</b>
Application Settings Command .....	69
Neural Net Manager Command .....	72
Missing Data Utilities Command .....	74
<b>More on Neural Networks</b>	<b>77</b>
<b>Neural Network Basics</b> .....	<b>77</b>
Neural Nets vs. Statistical Methods.....	77
The Structure of a Neural Net.....	78
Numeric and Category Prediction.....	78
Training a Net.....	78
Computer Processing of Neural Nets .....	79
Types of Neural Networks .....	79
<b>Multi-Layer Feedforward Nets</b> .....	<b>81</b>
MLF Architecture .....	81
MLF Net Training .....	83
<b>Generalized Regression Neural Nets and Probabilistic Neural Nets</b> .....	<b>87</b>
Generalized Regression Neural Nets .....	87
Probabilistic Neural Nets .....	89
<b>Comparison of MLF Nets to PN/GRN Nets</b> .....	<b>93</b>
<b>Input Transformation</b> .....	<b>95</b>
<b>Recommended Readings</b> .....	<b>97</b>
<b>Index</b>	<b>99</b>

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# Chapter 1: Getting Started

<b>Introduction</b> .....	<b>3</b>
Checking Your Package .....	3
What the Package Includes.....	3
About This Version .....	3
Working with your Operating Environment .....	4
If You Need Help .....	4
NeuralTools System Requirements.....	6
<b>Installation Instructions</b> .....	<b>7</b>
General Installation Instructions .....	7
Setting Up the NeuralTools Icons or Shortcuts.....	8



# Introduction

This introduction describes the contents of your NeuralTools package and shows you how to install NeuralTools and attach it to your copy of Microsoft Excel 2000 for Windows 2000 or higher.

## Checking Your Package

Your NeuralTools package should contain:

*The NeuralTools or DecisionTools Suite CD-ROM including:*

- *NeuralTools Program*
- *NeuralTools Tutorial*
- *The NeuralTools Users Guide (this book) in .PDF format*

*The NeuralTools Licensing Agreement*

If your package is not complete, please call your NeuralTools dealer or supplier or contact Palisade Corporation directly at (607) 277-8000.

## What the Package Includes

NeuralTools may be purchased on its own and also ships with the DecisionTools Suite Professional and Industrial versions. The NeuralTools CD-ROM contains the NeuralTools Excel add-in, several NeuralTools examples, and a fully-indexed NeuralTools on-line help system. The DecisionTools Suite Professional and Industrial versions contain all of the above plus additional applications.

## About This Version

This version of NeuralTools can be installed as a 32-bit program for Microsoft Excel 2000 or higher.

## Working with your Operating Environment

This User's Guide assumes that you have a general knowledge of the Windows operating system and Excel. In particular:

- *You are familiar with your computer and using the mouse.*
- *You are familiar with terms such as icons, click, double-click, menu, window, command and object.*
- *You understand basic concepts such as directory structures and file naming.*

## If You Need Help

Technical support is provided free of charge for all registered users of NeuralTools with a current maintenance plan, or is available on a per incident charge. To ensure that you are a registered user of NeuralTools, **please register online at <http://www.palisade.com/support/register.asp>**.

If you contact us by telephone, please have your serial number and User's Guide ready. We can offer better technical support if you are in front of your computer and ready to work.

### ***Before Calling***

Before contacting technical support, please review the following checklist:

- *Have you referred to the on-line help?*
- *Have you checked this User's Guide and reviewed the on-line multimedia tutorial?*
- *Have you read the README.WRI file? It contains current information on NeuralTools that may not be included in the manual.*
- *Can you duplicate the problem consistently? Can you duplicate the problem on a different computer or with a different model?*
- *Have you looked at our site on the World Wide Web? It can be found at <http://www.palisade.com>. Our Web site also contains the latest FAQ (a searchable database of tech support questions and answers) and NeuralTools patches in our Technical Support section. We recommend visiting our Web site regularly for all the latest information on NeuralTools and other Palisade software.*

## **Contacting Palisade**

Palisade Corporation welcomes your questions, comments or suggestions regarding NeuralTools. Contact our technical support staff using any of the following methods:

- *Email us at [support@palisade.com](mailto:support@palisade.com).*
- *Telephone us at (607) 277-8000 any weekday from 9:00 AM to 5:00 PM, EST. Follow the prompt to reach technical support.*
- *Fax us at (607) 277-8001.*
- *Mail us a letter at:*

**Technical Support  
Palisade Corporation  
798 Cascadilla St.  
Ithaca, NY 14850 USA**

If you want to contact Palisade Europe:

- *Email us at [support@palisade-europe.com](mailto:support@palisade-europe.com).*
- *Telephone us at +44 1895 425050 (UK).*
- *Fax us at +44 1895 425051 (UK).*
- *Mail us a letter at:*

**Palisade Europe  
31 The Green  
West Drayton  
Middlesex  
UB7 7PN  
United Kingdom**

If you want to contact Palisade Asia-Pacific:

- *Email us at [support@palisade.com.au](mailto:support@palisade.com.au).*
- *Telephone us at +61 2 9252 5922 (AU).*
- *Fax us at +61 2 9252 2820 (AU).*
- *Mail us a letter at:*

**Palisade Asia-Pacific Pty Limited  
Suite 404, Level 4  
20 Loftus Street  
Sydney NSW 2000  
Australia**

Regardless of how you contact us, please include the product name, version and serial number. The exact version can be found by selecting the Help About command on the NeuralTools menu in Excel.

## **Student Versions**

Telephone support is not available with the student version of NeuralTools. If you need help, we recommend the following alternatives:

- ◆ *Consult with your professor or teaching assistant.*
- ◆ *Log on to <http://www.palisade.com> for answers to frequently asked questions.*
- ◆ *Contact our technical support department via e-mail or fax.*

## **NeuralTools System Requirements**

System requirements for NeuralTools 5.0 for Microsoft Excel for Windows include:

- *Pentium PC or faster with a hard disk.*
- *Microsoft Windows 2000 SP4, Windows XP or higher.*
- *Microsoft Excel 2000 or higher.*

# Installation Instructions

## General Installation Instructions

The Setup program copies the NeuralTools system files into a directory you specify on your hard disk.

To run the Setup program in Windows 2000 or higher:

- 1) *Insert the NeuralTools or DecisionTools Suite CD-ROM in your CD-ROM drive*
- 2) *Click the Start button, click Settings and then click Control Panel*
- 3) *Double-click the Add/Remove Programs icon*
- 4) *On the Install/Uninstall tab, click the Install button*
- 5) *Follow the Setup instructions on the screen*

If you encounter problems while installing NeuralTools, verify that there is adequate space on the drive to which you're trying to install. After you've freed up adequate space, try rerunning the installation.

If you wish to remove NeuralTools from your computer, use the Control Panel's Add/Remove Programs utility and select the entry for NeuralTools.

### ***Removing NeuralTools from Your Computer***

**Creating the  
Shortcut in the  
Windows  
Taskbar**

## Setting Up the NeuralTools Icons or Shortcuts

In Windows, setup automatically creates a NeuralTools command in the Programs\Palisade DecisionTools menu of the Taskbar. However, if problems are encountered during Setup, or if you wish to do this manually another time, follow these directions. Note that the directions given below are for Windows XP Professional. Instructions for other operating systems may vary.

- 1) *Click the Start button, and then point to Settings.*
- 2) *Click Taskbar and Start Menu, and then click the Start Menu tab.*
- 3) *Click Customize, click Add, and then click Browse.*
- 4) *Locate the file NeuralTools.EXE, click it and then click OK.*
- 5) *Click Next, and then double-click the menu on which you want the program to appear.*
- 6) *Type the name "NeuralTools", and then click Finish.*
- 7) *Click OK on all opened dialogs.*

## The DecisionTools Suite

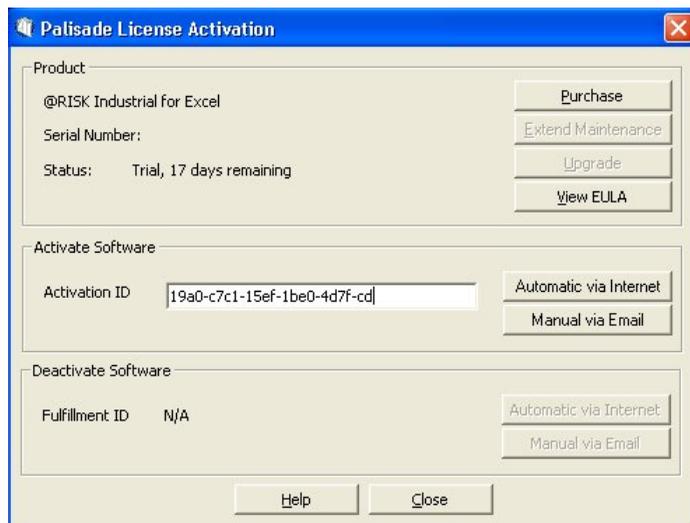
NeuralTools is part of the DecisionTools Suite, a set of products for risk and decision analysis available from Palisade Corporation. The default installation procedure of NeuralTools puts NeuralTools in a subdirectory of a main "Program Files\Palisade" directory. This is quite similar to how Excel is often installed into a subdirectory of a "Microsoft Office" directory.

One subdirectory of the Program Files\Palisade directory will be the NeuralTools directory (by default called NeuralTools5). This directory contains the NeuralTools add-in program file (NEURALTOOLS.XLA) plus example models and other files necessary for NeuralTools to run. Another subdirectory of Program Files\Palisade is the SYSTEM directory which contains files needed by every program in the DecisionTools Suite, including common help files and program libraries.



# Software Activation

Activation is a one time license verification process that is required in order for your NeuralTools software to run as a fully licensed product. An **activation code** is on your printed/ emailed invoice and may resemble a dash separated sequence like "19a0-c7c1-15ef-1be0-4d7f-cd". If you enter your Activation code during installation, then your software is activated the first time the software is run and no further user action is required. If you wish to activate your software after installation, select the NeuralTools Help menu License Activation command and enter your activation code in the displayed **Palisade License Activation** dialog box.



## **Frequently Asked Questions**

### **1) What if my software is not activated?**

If you do not enter an activation code during installation or you are installing a trial version, your software will run as a trial version with time and/or number of uses limitations and must be activated with an activation code in order to run as a fully licensed product.

### **2) How long can I use the product before I have to activate it?**

Software that is not activated may be run for fifteen days. All of the product's features are present, but the License Activation dialog will appear each time the program is launched to remind you to activate and to indicate the time remaining. If the 15 day trial period expires, the software will require activation in order to run.

### 3) How do I check my activation status?

The License Activation dialog box is viewed through the NeuralTools Help menu License Activation command. Activated software shows a status of **Activated** and trial version software shows a status of **Not Activated**. If the software is not activated, the remaining time that the software is allowed to run is displayed.

### 4) How do I activate my software?

If you do not have an activation code you may obtain one by clicking the Purchase button in the License Activation dialog. An online purchase will be immediately given an activation code and an optional link to download the installer should reinstallation become necessary. To purchase by phone call the local Palisade office given in the **Contacting Palisade** section of this chapter.

Activation may be done over the Internet or via email:

- **Activation if you have Internet Access**

In the Palisade License Activation dialog box, type or paste the activation code and press "Automatic via Internet". A success message should appear after a few seconds and the License Activation dialog box will reflect the software's activated status.

- **Activation if you do not have Internet Access**

Automated activation by email requires a few steps:

1. **Click "Manual via Email"** to display the request.xml file which you may save to disk or copy to the Windows clipboard. (It is recommended you note the location on your computer of the request.xml file.)
2. **Copy or attach the XML file** to an email and send it to *activation@palisade.com*. You should receive an automatic response to the return address in your email shortly.
3. **Save the response.xml attachment** in the response email to your hard drive.
4. **Click on the Process button** that is now in the Palisade License Activation dialog box and navigate to the response.xml file. Select the file and click OK.

A success message should appear and the License Activation dialog will reflect the software's activated status.

## 5) How do I transfer my software license to another machine?

Transfer of a license, or **rehosting**, may be performed through the Palisade License Activation dialog box as a two step procedure: *deactivation* on the first machine and *activation* on the second machine. A typical use of rehosting is to transfer your copy of NeuralTools from your office PC to your laptop. To rehost a license from *Machine1* to *Machine2*, make sure both machines have the software installed and are connected to the Internet during the deactivation/activation rehosting.

1. On *Machine1*, click deactivate **Automatic via Internet** in the License Activation dialog. Wait for the success message.
2. On *Machine2*, click activate **Automatic via Internet**. Wait for the success message.

If the machines do not have Internet access then you may follow the similar instructions above for rehosting by the automated email process.

## 6) I have Internet Access but I am still unable to Activate/Deactivate automatically.

Your firewall must be set to allow TCP access to the licensing server. For single user (non network installations) this is <http://service.palisade.com:8888> (TCP port 8888 on <http://service.palisade.com>).



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# Chapter 2: An Overview of NeuralTools

Overview .....	17
Why Neural Networks?.....	17
NeuralTools and Neural Networks .....	18
NeuralTools Menu and Toolbar.....	19
Data Sets and the Data Set Manager .....	19
Variable Types .....	21
Multi-Range Data .....	21
Training a Neural Network.....	21
Combining Training, Testing and Prediction .....	22
Net Configurations.....	22
Training Preview .....	23
Training Process .....	24
Training Reports.....	25
Testing a Network.....	26
Testing Reports .....	26
Prediction.....	27
Prediction Results.....	28
Live Prediction .....	28
NeuralTools Reports and Charts.....	29



# Overview

NeuralTools provides you with powerful neural network capabilities in an environment that you are familiar with - Microsoft Excel. NeuralTools procedures - such as defining data sets, training and testing neural networks and predicting values using trained networks - can be run on your data in Excel and the reports and charts from your analyses are created in Excel.

## Why Neural Networks?

Neural Networks are capable of learning complex relationships in data. By mimicking the functions of the brain, they can discern patterns in data, and then extrapolate predictions when given new data. The problems Neural Networks are used for can be divided in two general groups:

- **Classification Problems:** Problems in which you are trying to determine what type of category an unknown item falls into. Examples include medical diagnoses and prediction of credit repayment ability.
- **Numeric Problems:** Situations where you need to predict a specific numeric outcome. Examples include stock price forecasting and predicting the level of sales during a future time period.

NeuralTools comes with examples that show how to apply neural networks to different prediction problems. The **NeuralTools\Examples** folder contains the provided examples as Excel workbooks.

## NeuralTools and Neural Networks

When using NeuralTools, neural networks are developed and used in four steps:

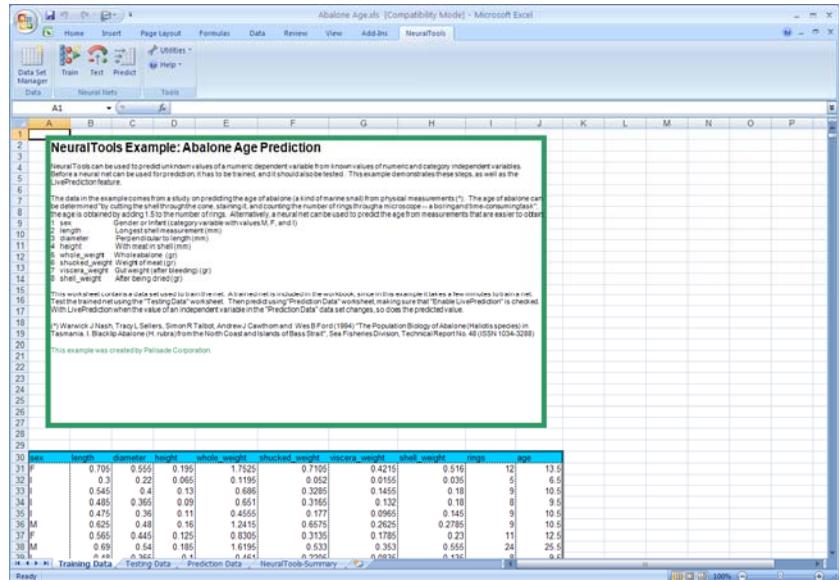
- **Data Preparation** - The data you use in NeuralTools is defined in data sets. A **Data Set Manager** is used to set up data sets so they can be used over and over again with your neural networks.
- **Training** - With training, a neural network is generated from a data set comprised of cases with known output values. This data often consists of historical cases for which you know the values of output/dependent variable.
- **Testing** - With testing, a trained neural network is tested to see how well it does at predicting known output values. The data used for testing is usually a subset of your historical data. This subset was not used in training the network. After testing, the performance of the network is measured by statistics such as the % of the known answers it correctly predicted.
- **Prediction** - A trained neural network is used to predict unknown output values. Once trained and tested, the network can be used as needed to predict outputs for new case data.

Training and testing are an iterative, sometimes time-intensive process. Typically, you may train several different times with different settings in order to generate a neural network that tests best. Once you have your "best net" you can quickly use it for predicting.

Now, let's look at how NeuralTools works in Excel and how you define data sets and train and test neural networks using those data sets. Then we will predict unknown output values using trained networks.

# NeuralTools Menu and Toolbar

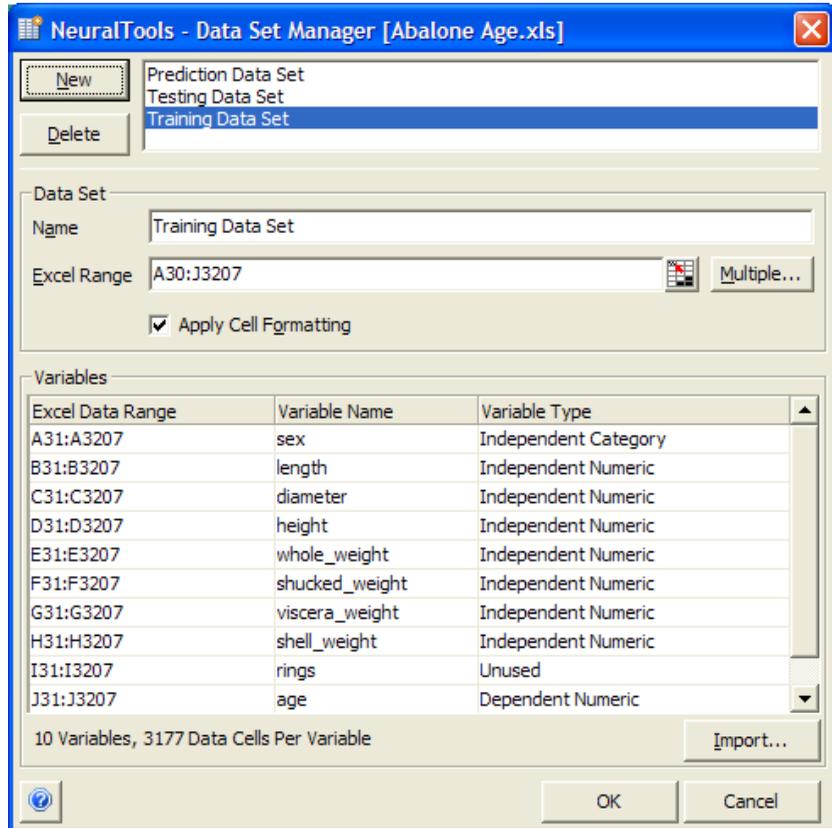
Once you have installed NeuralTools, its menu and commands will be included as part of the Excel menu bar in Excel 2003 and earlier. There will also be a NeuralTools toolbar displayed. The menu shows commands for 1) defining your data in data sets, 2) training and testing neural networks and 3) predicting values using trained neural networks. In Excel 2007, all commands are available via the NeuralTools ribbon bar.



# Data Sets and the Data Set Manager

Data in NeuralTools is structured around **cases** and **variables**. You work with a data set, or a set of statistical variables, located in contiguous columns with variable names in the first row of the data set. Each row in the data set is a **case**. Each case has a set of independent variable values and either a known or missing value for the dependent output variable. It is the job of NeuralTools to predict output variable values for cases where they are not known.

The NeuralTools **Data Set Manager** allows you to define your data sets, variables and cases. You can then use these predefined variables for training and testing neural networks, without re-selecting the data you wish to analyze over and over. You may place all known, historical cases in one data set and cases you wish to predict results for in a different data set. You can also combine all your data – known historical data and data you wish to predict - in a single data set.



Each variable in a data set has a name and a range of Excel cells associated with it. Each column within the range contains data for a different variable. A data set can include multiple blocks of cells, allowing you to put data on different sheets in the same workbook.

When you are defining a data set, NeuralTools attempts to identify the variables in a block of cells surrounding the current selection in Excel. This makes it quick and easy to set up a data set with variable names in the top row and variables laid out by column.

## Variable Types

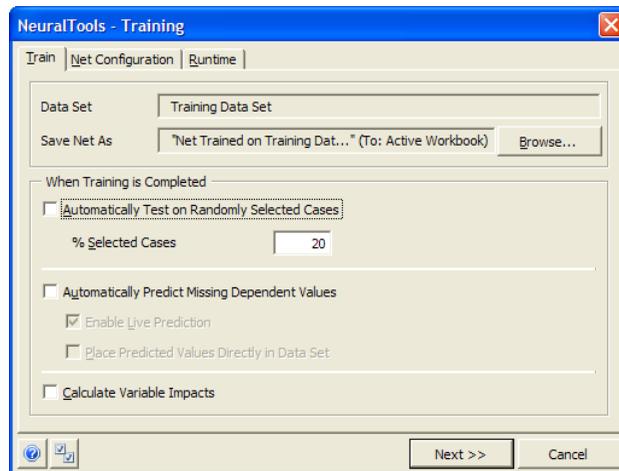
In NeuralTools, variables can be independent or dependent and numeric or categorical (for example *Yes* or *No*, or *Red*, *Green* or *Blue*.) The Data Set Manager attempts to identify the type of each variable in your data set, but you can override this with your own selections.

## Multi-Range Data

A single column in an Excel 2003 or earlier worksheet can hold up to 65,536 data points for a variable. If your variables have more values than this and you choose not to adopt Excel 2007, NeuralTools allows multiple cell ranges to be assigned to a single data set. In other words, you can "repeat" a data set across multiple sheets, assigning the same columns in different worksheets to hold all the values for a data set.

## Training a Neural Network

After you have defined a data set that contains cases with known historical values, you can train a neural network using that data. There are different options that determine the type of network that will be generated by NeuralTools. Depending on the nature of your data, different network options will generate better performing trained networks (i.e. networks that do a better job predicting answers). The testing process – done following training – gives precise measurements of how well your trained network does at predicting output values.



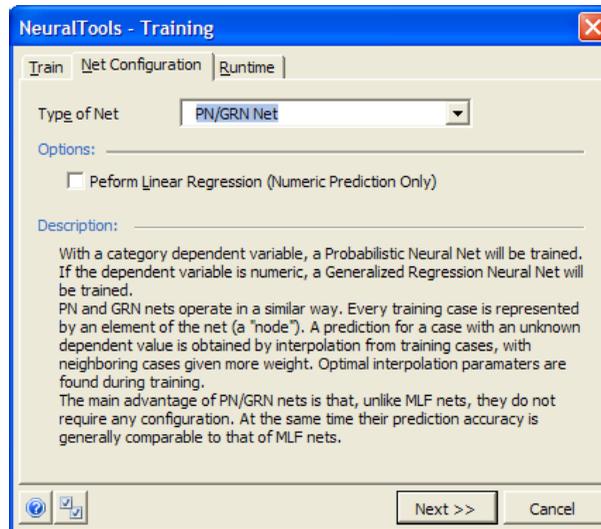
Training a neural network, along with testing and prediction, requires that you specify a data set that contains the data to be used during training. NeuralTools will either save your trained network directly in your workbook or optionally, to a file on disk.

## Combining Training, Testing and Prediction

If all your data is in a single data set (including both known historical data and new data where you do not know output values), NeuralTools allows you to train and test a network, then predict output values, all in a single step. You select to withhold a certain percentage of the historical data for testing (20% is shown on the prior page) and then select to automatically predict output values for cases with missing dependent values. By doing this you quickly can get the answers you need in one operation.

## Net Configurations

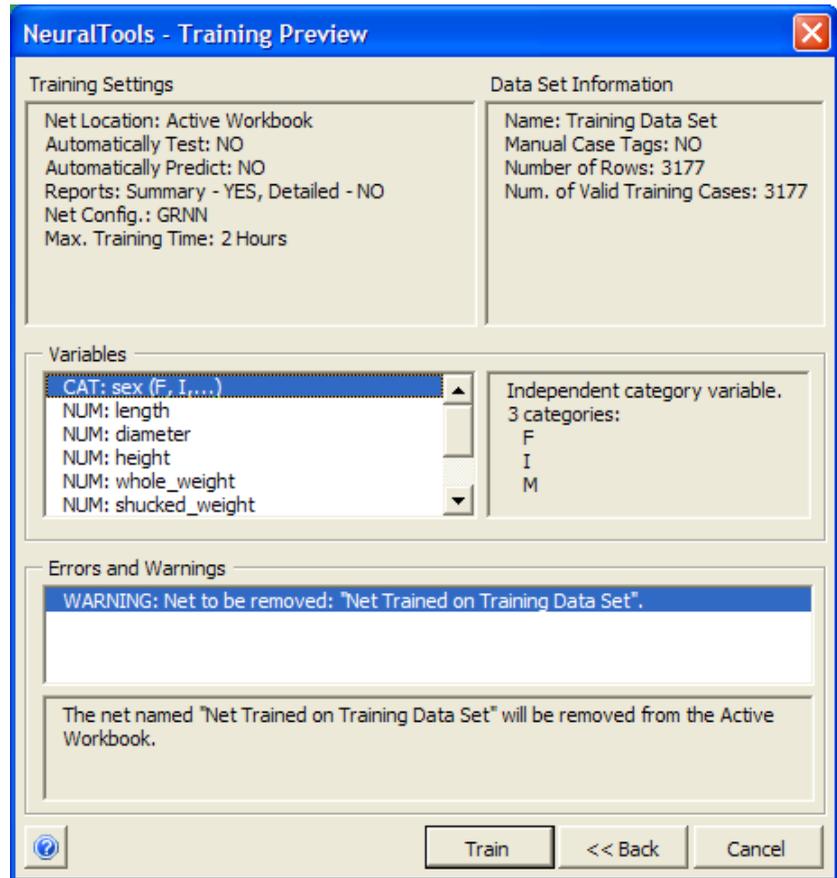
NeuralTools supports different neural network configurations to give the best possible predictions. For classification/category prediction (where the dependent variable is a category type), two types of networks are available: **Probabilistic Neural Networks (PNN)** and **Multi-Layer Feedforward Networks (MLF)**. Numeric prediction can be performed using MLF networks, as well as **Generalized Regression Neural Networks (GRNN)**, which are closely related to PNN networks.



NeuralTools makes selecting a network configuration easy by offering a **Best Net** search. When selected, NeuralTools will train and test a variety of neural network configurations to generate the one that gives the best predictions for your data. The best configuration is determined based on testing data, so for Best Net search the "Automatically Test" option needs to be selected in the Train tab.

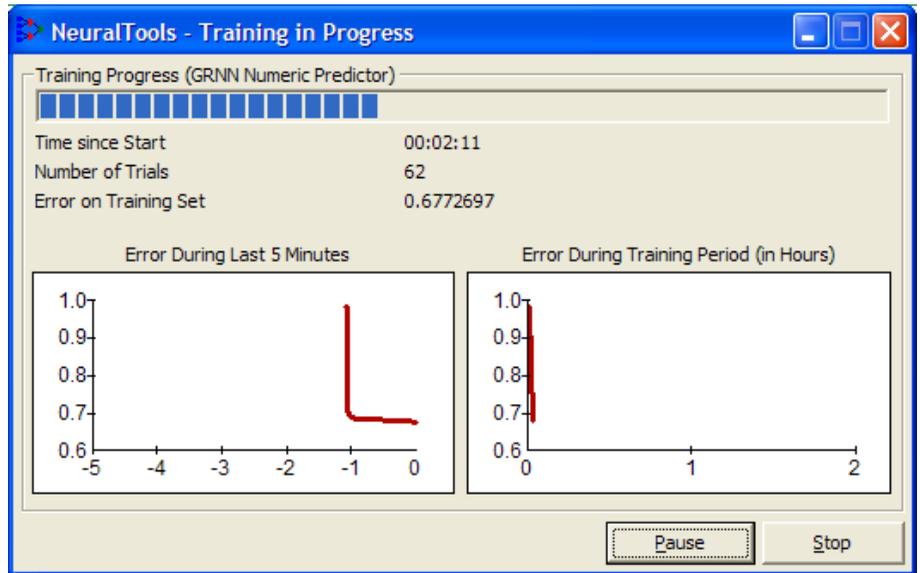
## Training Preview

Once training and network configuration options are selected, NeuralTools previews what it will perform during network training. Since training is the most time-intensive process in neural network modeling, it helps to review the training setup prior to proceeding. NeuralTools will try to identify any problems it has found in your data so you can correct them prior to proceeding with training.



## Training Process

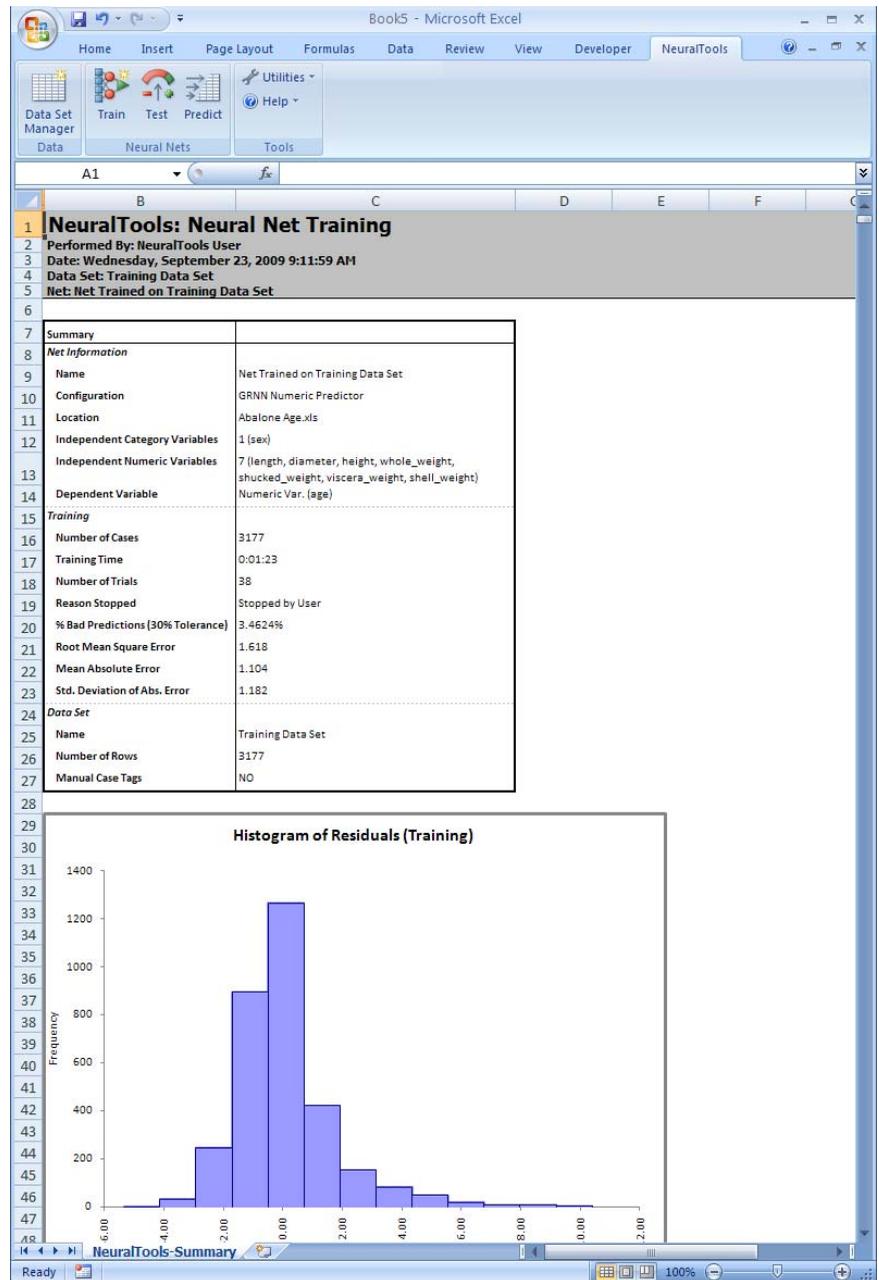
As NeuralTools proceeds with training a neural net on your data, it reports how well it is doing. Typically the net gets better and better as training proceeds, as NeuralTools generates networks that make better predictions on your data with fewer errors. Graphs update to show NeuralTools' progress during training.



Training stops when any of the stopping conditions you have set – such as maximum training time – are reached. If you have selected to automatically test the net or predict missing output values in your data set, this will be performed after training.

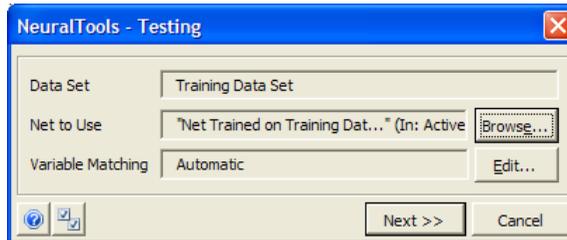
## Training Reports

Training reports show how well your trained net performed. Statistics such as % **Bad Predictions** show the number of cases in the training set for which the network predicted an output value that did not agree with the actual known value.



## Testing a Network

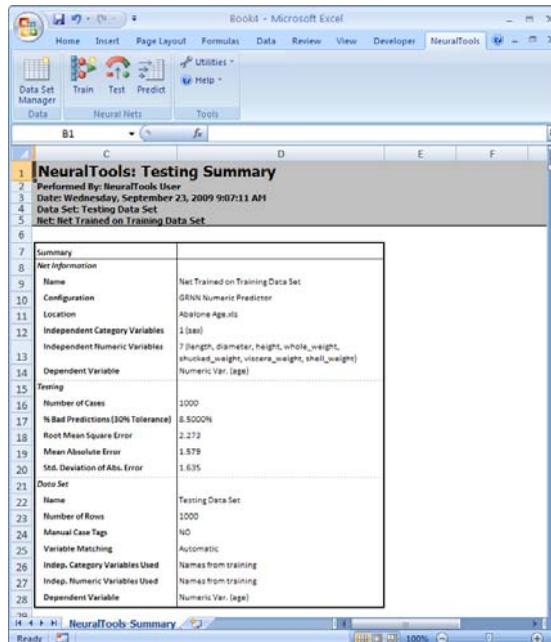
During testing, a trained neural network is tested to see how well it does at predicting known output values. The testing data is usually a subset of your historical data with known output values. This subset was not used in training the network.



When testing data is in a separate data set, NeuralTools will match the variables in the testing data set with those in the training data. As with training, NeuralTools will preview your testing setup prior to running.

### Testing Reports

Testing (along with prediction) runs much faster than training. NeuralTools reports how well it did in predicting the known answers in the testing data. This helps you see if the network will be a good predictor when applied to cases with unknown output values.

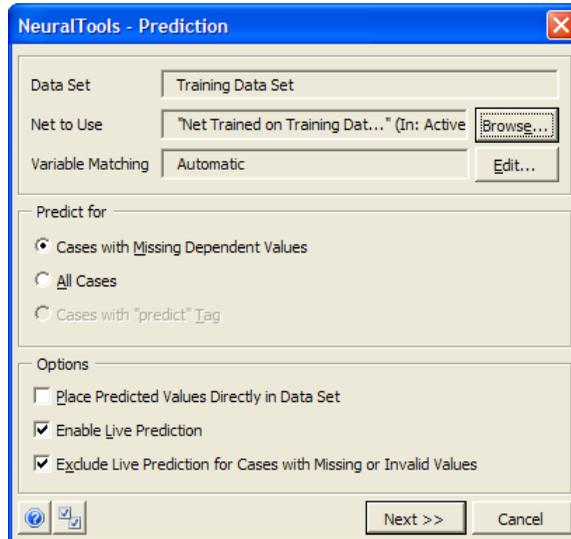


NeuralTools: Testing Summary	
Performed By: NeuralTools User	
Date: Wednesday, September 23, 2009 9:07:11 AM	
Data Set: Testing Data Set	
Net: Net Trained on Training Data Set	
Summary	
Net Information	
Name	Net Trained on Training Data Set
Configuration	GRNN Numeric Predictor
Location	Abalone Ag.xls
Independent Category Variables	1 (sex)
Independent Numeric Variables	7 (length, diameter, height, whole_weight, shucked_weight, viscera_weight, shell_weight)
Dependent Variable	Numeric Var: (age)
Testing	
Number of Cases	1000
% Bad Predictions (30% Tolerance)	8.5000%
Root Mean Square Error	2.273
Mean Absolute Error	1.878
Std. Deviation of Abs. Error	1.635
Data Set	
Name	Testing Data Set
Number of Rows	1000
Manual Case Tags	NO
Variable Matching	Automatic
Indep. Category Variables Used	Names from training
Indep. Numeric Variables Used	Names from training
Dependent Variable	Numeric Var: (age)

## Prediction

The end use of a neural network is prediction. You will apply a trained network to new cases where you do not know output values but you want to predict them. NeuralTools offers two methods for prediction – 1) **a command-driven method for predicting values** for cases in a data set, and 2) **Live Prediction (Industrial version only)**, where the independent variable values for a case in your worksheet can be entered and NeuralTools will automatically calculate the predicted output value.

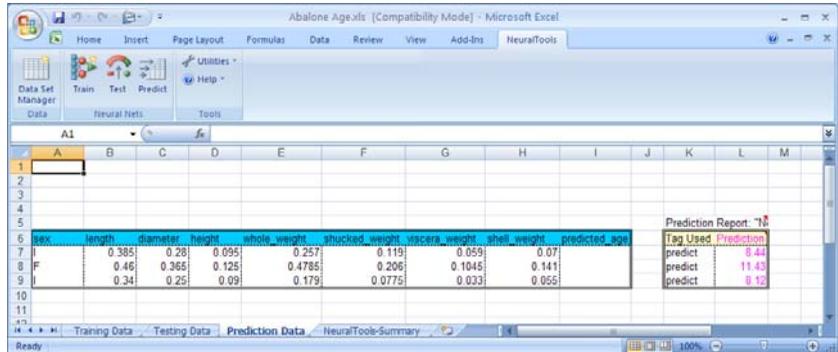
When you wish to predict values for a group of cases in a data set, the Prediction dialog helps you set up the prediction process. You can predict for just cases with missing output values and optionally enable Live Prediction so you can make modifications to your data to see how it will affect predictions. Different trained nets can be used to see how predicted values will differ.



As with training and testing, NeuralTools first previews the data and setup it will use for prediction. Then, predictions are reported to your worksheet in Excel.

## Prediction Results

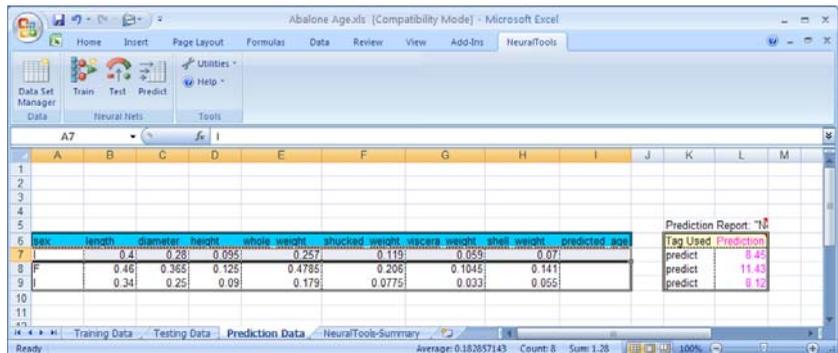
Predicted output values are shown next to the cases for which prediction is performed. In the screen here, predicted values are in purple.



Case	length	diameter	height	whole weight	shucked weight	viscera weight	shell weight	predicted age
I	0.385	0.28	0.095	0.257	0.119	0.059	0.07	8.44
F	0.46	0.365	0.125	0.4785	0.206	0.1045	0.141	11.43
I	0.34	0.25	0.09	0.179	0.0775	0.033	0.055	8.12

## Live Prediction

When Live Prediction is enabled, NeuralTools automatically adds an Excel formula to the cell where the predicted value is shown. This formula generates the predicted value, so if you change independent variable values for a case, the predicted value will be automatically recalculated. Using Live Prediction you can simply type data for new cases directly in Excel and automatically generate a new prediction, without going through the Prediction dialog. For example, if the independent variable values for the case in row 7 in the above worksheet are changed as shown, the predicted value automatically updates. As with any worksheet cell, you can reference a LivePrediction cell in any Excel formula.

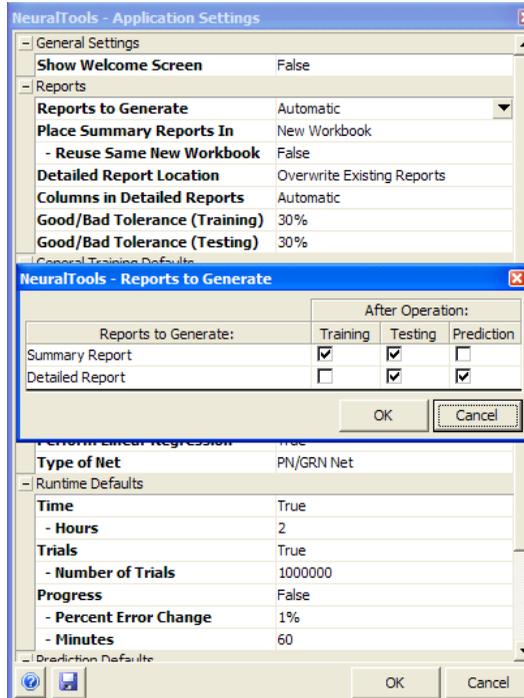


Case	length	diameter	height	whole weight	shucked weight	viscera weight	shell weight	predicted age
I	0.4	0.28	0.095	0.257	0.119	0.059	0.07	8.45
F	0.46	0.365	0.125	0.4785	0.206	0.1045	0.141	11.43
I	0.34	0.25	0.09	0.179	0.0775	0.033	0.055	8.12

(Note: Live Prediction is available in the Industrial version only.)

## NeuralTools Reports and Charts

NeuralTools creates both Summary and Detailed Reports from training, testing and prediction. **Summary Reports** are shown on their own worksheet and have overall information on Testing or Training. A **Detailed Report** gives information on a case-by-case basis and is shown next to the data being reported on. In addition, most of the Summary Report information can be found inside the Detailed Report as a comment added to the title cell; that version of the Summary Report is referred to as the **Quick Summary**.



Whenever NeuralTools creates one or more charts, it places them with the reports. Charts are created in Excel format and may be customized using standard Excel chart commands.

## NeuralTools Utilities

Two utilities are provided to help you to manage neural network modeling in NeuralTools. A **Neural Net Manager** allows you to copy or move trained neural networks between workbooks and files. A **Missing Data** utility helps identify and correct cases with missing data in your data sets.

## Using NeuralTools with StatTools, Solver and Evolver

NeuralTools is designed to be used with **StatTools**, the statistics add-in for Excel from Palisade. Both products share the same Data Set Manager; data sets defined in NeuralTools can be analyzed in StatTools and vice versa. Using StatTools, you can calculate statistics on variables in data sets defined in NeuralTools along with statistics on predictions generated by NeuralTools.

Detailed Reports generated in NeuralTools are immediately available for analysis in StatTools; they automatically show on the list of data sets in StatTools Data Set Manager. This facilitates the use of StatTools to obtain statistical results beyond those contained in NeuralTools' Summary Reports. For example, a testing Summary Report includes a histogram of residuals (defined as differences between actual and predicted values). Based on the histogram, the residuals may appear to be approximately normally distributed. To test the hypothesis of normal distribution, one of StatTools' normality tests can be applied to the Residuals variable in the Detailed Report. An example is provided in the file "Abalone Age Prediction with StatTools Analysis.xls".

NeuralTools' Live Prediction feature makes it easy to see how changes to independent values affect the prediction. With Live Prediction, other tools available in Excel can be used to explore the relationship between independent variables and the dependent one.

**Solver** – Excel's built in optimizer can be used with NeuralTools' Live Prediction capability to calculate optimal decision values for predictions made in NeuralTools. The file "Auto Loans with Solver.xls" provides an example. In the example, a neural net is used to predict whether a borrower will be making timely payments. However, the network may only be 60% confident of the answer. Excel's Solver could then be used to determine a loan amount where the network would be 90% sure that the individual will be making timely payments. In this case, the optimizer would try different loan amounts while NeuralTools automatically updated the probability value. **Evolver**, Palisade's genetic algorithm based optimizer, can be used instead of Solver to find the answer. Unlike Solver, Evolver can handle optimization problems in which there is more than one local optimum.

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# Chapter 3: NeuralTools Reference Guide

<b>Introduction</b> .....	<b>33</b>
<b>Reference: NeuralTools Icons</b>	<b>35</b>
<b>NeuralTools Toolbar</b> .....	<b>35</b>
<b>Reference: NeuralTools Menu Commands</b>	<b>37</b>
<b>Introduction</b> .....	<b>37</b>
Icons in Dialog Boxes .....	38
<b>Command Reference</b> .....	<b>39</b>
Data Set Manager Command .....	39
Train Command .....	44
Test Command .....	56
Predict Command .....	64
<b>Utilities</b> .....	<b>69</b>
Application Settings Command .....	69
Neural Net Manager Command .....	72
Missing Data Utilities Command .....	74
<b>More on Neural Networks</b>	<b>77</b>



# Introduction

The NeuralTools Reference Guide chapter describes the icons, commands, and statistics functions used by NeuralTools. This chapter is divided into two sections:

- 1) *Reference: NeuralTools Icons*
- 2) *Reference: NeuralTools Menu Commands*



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# Reference: NeuralTools Icons

## NeuralTools Toolbar

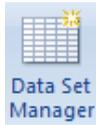
NeuralTools icons are used to define data sets with cases and variables and then create and use neural networks on that data. NeuralTools icons appear on the Excel toolbar (i.e., as a custom toolbar in Excel) in Excel 2003 and earlier and on a ribbon in Excel 2007. This section briefly describes each icon, outlining the functions they perform and the menu command equivalents associated with them. In Excel 2007, all commands are available via the NeuralTools ribbon bar.

The following icons are shown on the NeuralTools toolbar in Excel 2003 and earlier and/or in NeuralTools dialog boxes.

<b>Icon</b>	<b>Function Performed and Command Equivalent</b>
	<b>Define a data set and variables, or edit or delete an existing data set and variables</b> <i>Command equivalent: Data Set Manager command</i>
	<b>Train a neural network</b> <i>Command equivalent: Train command</i>
	<b>Test a neural network</b> <i>Command equivalent: Test command</i>
	<b>Predict values using a trained network</b> <i>Command equivalent: Predict command</i>
	<b>Run neural network utilities</b> <i>Command equivalent: Utilities command</i>
	<b>Display NeuralTools help file</b> <i>Command equivalent: Help command</i>

The following icons are shown on the NeuralTools ribbon in Excel 2007.

**Icon      Function Performed and Command Equivalent**



**Define a data set and variables, or edit or delete an existing data set and variables**

*Command equivalent: Data Set Manager command*



**Train a neural network**

*Command equivalent: Train command*



**Test a neural network**

*Command equivalent: Test command*



**Predict values using a trained network**

*Command equivalent: Predict command*



**Run neural network utilities**

*Command equivalent: Utilities command*



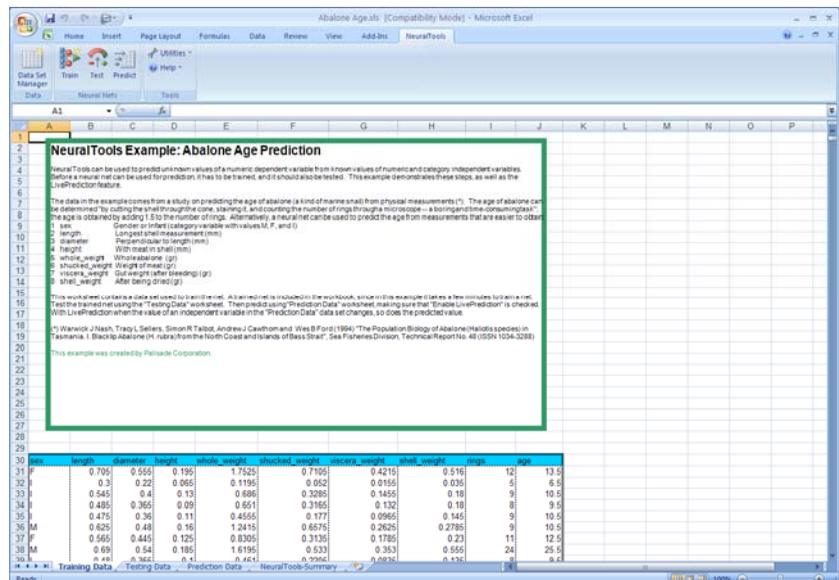
**Display NeuralTools help file**

*Command equivalent: Help command*

# Reference: NeuralTools Menu Commands

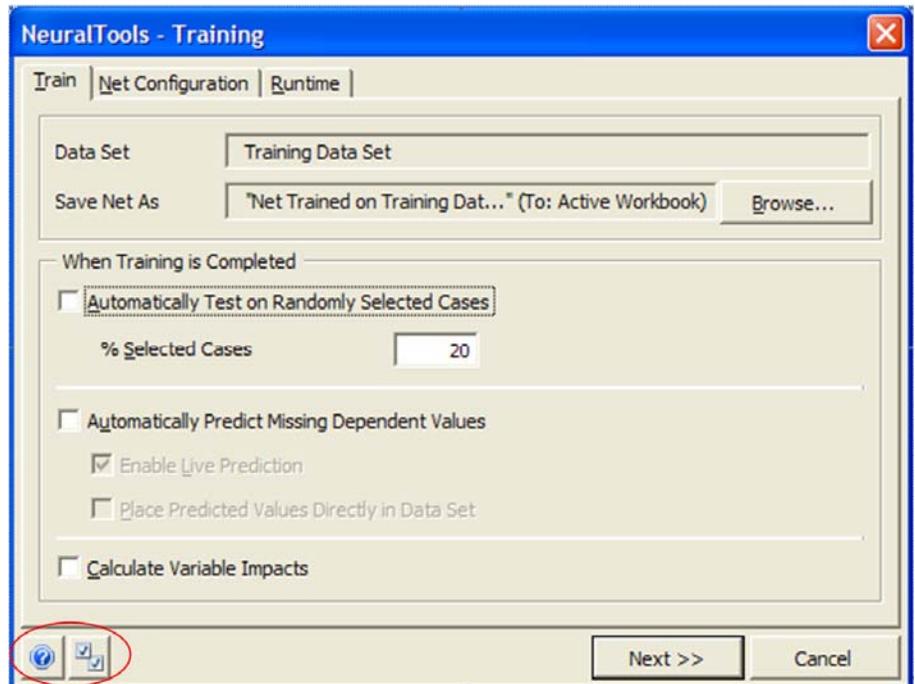
## Introduction

This section of the Reference Guide details the available NeuralTools commands as they appear on the NeuralTools menu or ribbon in Excel. Commands are discussed as they appear on the menu, starting with the Data Set Manager command and subsequently moving down. NeuralTools icons can be used to perform many of the available commands. The **Reference: NeuralTools Icons** section of this chapter gives the command equivalents for each NeuralTools icon.



## Icons in Dialog Boxes

Up to two icons – the **Help icon** and the **Application Settings icon** – may appear in individual NeuralTools dialog boxes. The Help icon allows you to quickly access the help topic on the relevant dialog. The Application Settings icon displays the Application Settings dialog where you can enter or edit settings for NeuralTools reports, as well as default settings for Training, Prediction and Runtime.



# Command Reference

## Data Set Manager Command

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**Defines NeuralTools data sets and variables, or edits or deletes an existing data set and variables**

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The **Data Set Manager** command allows you to define your data sets with cases and variables. Once data sets are defined, they may be used for neural network training, testing and prediction. The Data Set Manager dialog box allows you to add or remove data sets, name a data set, specify the layout of the variables in a data set, and name the variables in a data set.

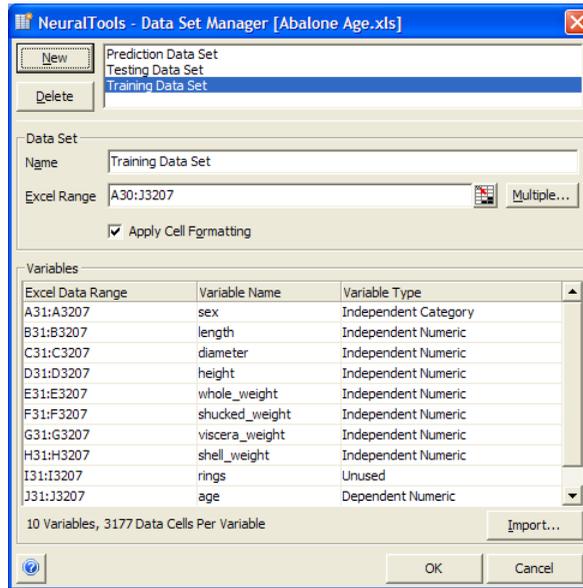
### ***What Are Data Sets and Variables?***

NeuralTools is structured around variables and cases. You work with a data set, or a set of statistical variables, located in contiguous columns in an Excel worksheet with variable names in the first row of the data set. Each row in the data set is a **case**. Each case has a set of independent variable values and either a known or missing value for the dependent output variable.

Each variable in a data set has a name and a range of Excel cells associated with it. A data set can include multiple blocks of cells, allowing you to put data on different sheets in the same workbook.

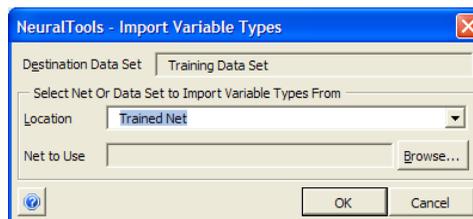
When you are defining a data set, NeuralTools attempts to identify the variables in a block of cells surrounding the current selection in Excel. This can make it quick and easy to set up a data set with variable names in the top row and variables laid out by column.

## Data Set Manager Dialog Box



The Data Set options in the Data Set Manager dialog box include:

- **New, Delete** – adds a new data set, or deletes an existing one.
- **Name** – specifies the name of the data set.
- **Excel Range** – specifies the Excel Range associated with a data set. If multiple cell ranges have been assigned to a data set this entry will be prefaced by the label **Multiple**.
- **Apply Cell Formatting** - adds a grid and colors that identify your data sets.
- **Multiple** - clicking the **Multiple** button in the Data Set Manager dialog box displays the **Multiple Range Selector** dialog. This dialog allows the entry of individual cell ranges that comprise the multiple cell range data set.
- **Import** – allows variable types to be copied to this data set from another data set or trained neural net. The Import Variable Types dialog allows you to select the location and net to use for variable definitions.

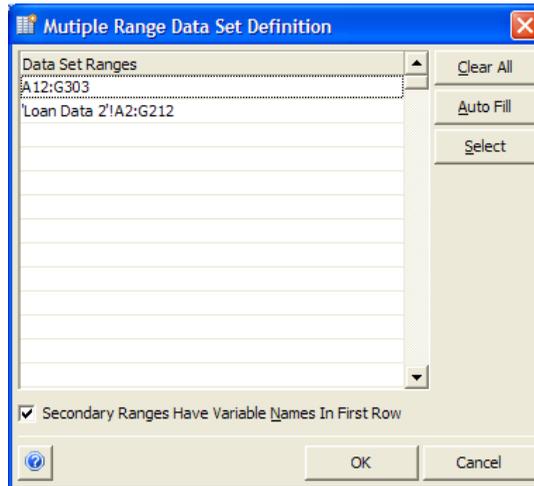


## Multiple Range Data Sets

NeuralTools allows multiple cell ranges on different worksheets to be assigned to a single data set. A multiple range data set can be used when:

- 1) Each variable in a data set has more than 65,536 data points in an Excel 2003 or earlier worksheet, requiring the data set to extend across multiple worksheets in the same workbook,
- 2) The data for a variable is located in multiple blocks scattered throughout the worksheets in a workbook.

*Note: A multiple range data set cannot be defined within a single worksheet. They can be defined on multiple worksheets within the same workbook.*

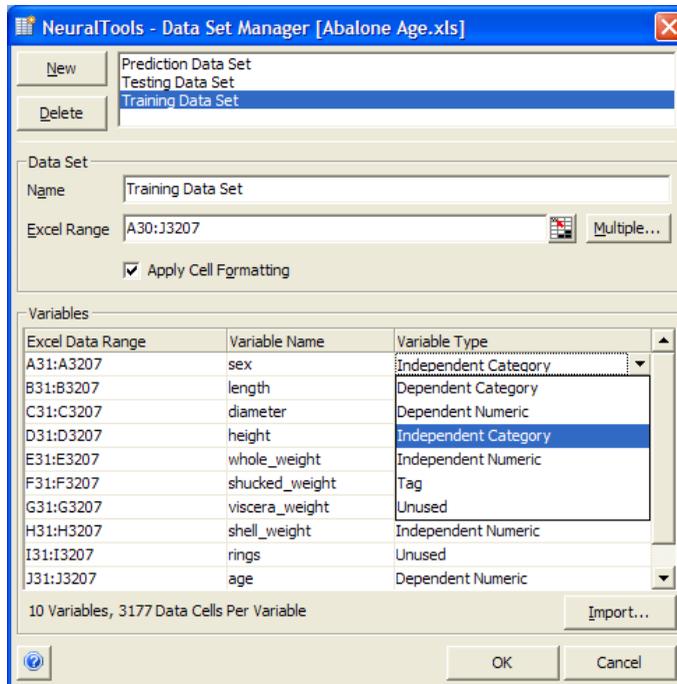


The options in the Multiple Range Selector dialog include:

- **Clear All** – Clears all entered ranges.
- **Auto Fill** – Applies the first range entered (in row 1) to all visible worksheets in the active workbook, and enters these *SheetName!CellRange* references in the grid
- **Select** – Displays a selector for highlighting a block of cells to be used as a Data Set Range.
- **Secondary Ranges Have Variable Names in the First Column (Row)** - Multiple range data sets can have variable names labeling each column in each range listed in the dialog, or variable names labeling columns in just the first selected range. The first selected range is the range entered in row 1 of the Multiple Range Selector dialog.

## Variable Options

Each row in the grid in the Data Set Manager dialog box lists the variables in a data set, including the **Excel Data Range** that holds the data points for a variable, the **Variable Name**, and the **Variable Type**.



The **Variable Type** options include:

- **Dependent Category** – dependent or output variable whose possible values are taken from a set of possible categories; for example *Yes* or *No*, or *Red*, *Green* or *Blue*.
- **Dependent Numeric** – dependent or output variable whose possible values are numeric.
- **Independent Category** – an independent variable whose possible values are taken from a set of possible categories; for example *Yes* or *No*, or *Red*, *Green* or *Blue*.
- **Independent Numeric** – an independent variable whose possible values are numeric.
- **Tag** – a variable that takes the possible values "train", "test" or "predict". This type of variable is used to identify cases in a data set that will be used for training, testing and prediction.
- **Unused** – a variable in a data set that will not be used in a neural net.

## **More on Tag Variables**

**Tag variables** are a special type of variable in a NeuralTools dataset that are used to identify cases in a data set that will be used for training, testing and prediction. They are especially useful when you want to include all data (to be used for network training, testing and prediction) in a single dataset. When you have a tag variable, NeuralTools selects the cases to use for training, testing or prediction based on the tag variable's value. By changing tag variable values, you can retrain a network using different cases and see how network performance changes. You can also add new cases with unknown dependent variable values to a dataset and assign them to be predicted using the "Predict" tag. A Tag variable can take only three possible values:

- **Train** - specifies that the case will be used for training
- **Test** - specifies that the case will be used for testing
- **Predict** - specifies that the case will be used for prediction

*Note: If you have a tag variable in your data set, options in the Training dialog will change. See the Train command for more information.*

## **Data Set and Variable Capacities**

In a single session, NeuralTools allows:

- Up to 256 data sets, located in a single workbook.
- Up to 16384 variables per data set in Excel 2007 (256 variables in earlier versions of Excel). All the data for a single data set must be located in the same workbook.
- Number of data points per variable and cases per data set limited only by available memory in Excel 2007 (16,777,216 data points in earlier versions of Excel).

Actual data capacities may be less than shown above depending on the system configuration and version of Excel in use. Memory limitations of Excel itself may also affect data capacities.

*Note: the Data Set Manager dialog box lists all data sets and variables in the active workbook (this is the workbook listed in the caption of the Data Set Manager dialog). To list data sets in other workbooks, activate the desired workbook in Excel and display the Data Set Manager dialog.*

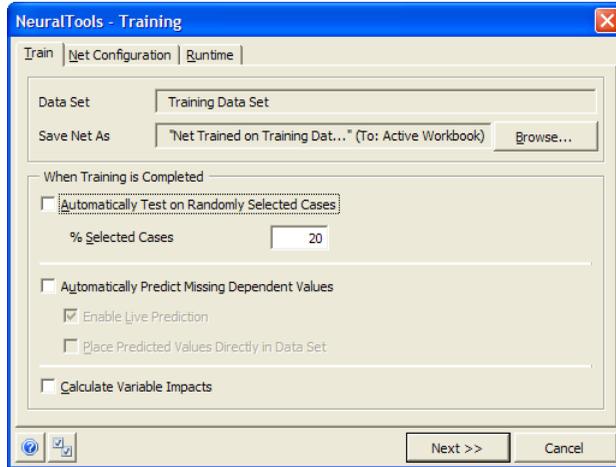
# Train Command

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**Specifies settings for training a neural network and runs the training**

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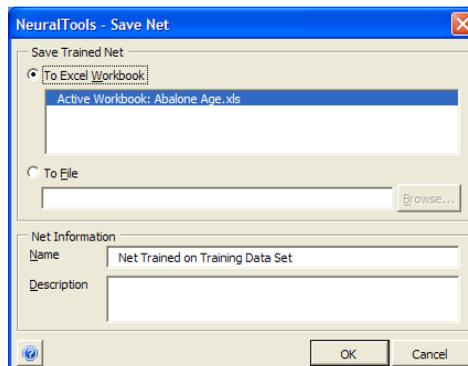
The **Train** command allows you to 1) specify settings to be used for training a neural network in NeuralTools and 2) start training a net.



## **Train Tab**

The **Train** tab in the Training dialog box specifies general options for training a neural network. It includes the following:

- **Data Set** – shows the data set to be used when training the neural network. This data set needs to be defined using the Data Set Manager and present in the active sheet.
- **Save Net As** – specifies the name and location for the neural net to be trained. Neural networks may be saved to an Excel workbook or to a file on disk. Click **Browse...** to change the name or location shown.



You may also enter a name and description for the neural network to be saved.

The **When Training is Completed** options allow you to automatically test and predict using the trained net following training. This can be done when the data to test and predict is located in the same data set with the training data.

- **Automatically Test on** – specifies that either:
  - 1) a % of the cases in the data set will automatically be "held out" from training to be used for testing
  - 2) cases where the Tag variable = "test" will be used for testing. A tag variable is a variable type as specified in the Data Set Manager.
- **Automatically Predict Missing Dependent Values** – specifies that the trained net will be used to predict dependent variable values for either:
  - 1) cases where the dependent variable value is missing, or
  - 2) cases where the Tag variable = "predict". A tag variable is a variable type as specified in the Data Set Manager.
- **Enable Live Prediction** – specifies that NeuralTools will place formulas in the cells where the predicted dependent variable values are shown to calculate the predicted values. For more on Live Prediction, see the Predict command in this chapter.
- **Calculate Variable Impacts** – specifies that NeuralTools will calculate the relative impact of each independent variable in the training data set in determining the predictions calculated by the net.

### ***What is Variable Impact Analysis?***

The purpose of **Variable Impact** analysis is to measure the sensitivity of net predictions to changes in independent variables. This analysis is only done on training data. As a result of the analysis, every independent variable is assigned a "Relative Variable Impact" value; these are percent values and add to 100%. The lower the percent value for a given variable, the less that variable affects the predictions. The results of the analysis can help in the selection of a new set of independent variables, one that will allow more accurate predictions. For example, a variable with a low impact value can be eliminated in favor of some new variable. However, one needs to keep in mind that the results of the Impact Analysis are relative to a given net. The fact

that one net "learned" to disregard a given variable makes it likely that another net will also "learn" to disregard it; but then again, another training session with a different type of net might "discover" how the variable can make a significant contribution to accurate predictions. In data sets with smaller numbers of cases and/or larger numbers of variables, the differences in the relative impact of the variables between trained nets may be more pronounced. Also, it is important to remember that these values are "relative". Suppose that with two independent variables one is assigned 99%, and the other 1%. This means that the latter is much less important than the former, but does not mean that it is unimportant, particularly if high accuracy of predictions is desired.

Some additional points to note about Variable Impact Analysis include:

- 1) Only the training data set is included in the analysis. (If Auto-Testing or Auto-Prediction are used, those cases are not included. The reason is that they might have numeric values outside the training range, which could make analysis results more unpredictable.)
- 2) For a given category independent variable, for every case the analysis steps through all the valid categories for that variable, and measures the change to the predicted value. (With category prediction there is no numeric predicted value, but there are raw numeric net outputs on which the category prediction is based; those numeric outputs are used by the analysis.)
- 3) For a given numeric independent variable, for every case the analysis steps through the range from the minimum to the maximum training value for that variable, measuring the change to the predicted value (or, in the case of category prediction, change to the raw numeric outputs).

The purpose of the Variable Impact Analysis is not meant to support firm conclusions, like stating with high confidence that a given variable is irrelevant. Instead, it's meant to help in a search for the best set of independent variables: the results of the analysis may be telling us that a given variable looks irrelevant, sufficiently so that it's worth trying to train a net without this variable.

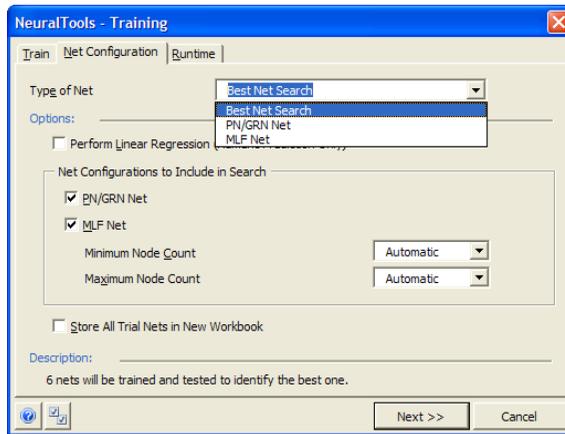
The results of a Variable Impact analysis are displayed in the Training Summary report:

NeuralTools	
(Report: Neural Net Training)	
Created for: Test	
Date: Wednesday, February 18, 2009	
<b>Summary</b>	
<b>Net Information</b>	
Name	Net Trained on Training Data Set
Configuration	GRNN Numeric Predictor
Location	Abalone Age.xls
Independent Category Variables	1 (sex)
Independent Numeric Variables	7 (length, diameter, height, whole_weight, shucked_weight, viscera_weight, shell_weight)
Dependent Variable	Numeric Var. (age)
<b>Training</b>	
Number of Cases	3177
Training Time (h:min:sec)	0:02:26
Number of Trials	68
Reason Stopped	Stopped by User
% Bad Predictions (30% Tolerance)	4.9418%
Root Mean Square Error	1.816
Mean Absolute Error	1.255
Std. Deviation of Abs. Error	1.314
<b>Data Set</b>	
Name	Training Data Set
Number of Rows	3177
Manual Case Tags	NO
<b>Variable Impact Analysis</b>	
shell_weight	46.5202%
shucked_weight	15.0231%
height	13.5240%
diameter	8.2382%
length	7.3342%
sex	4.1137%
whole_weight	2.8459%
viscera_weight	2.4007%

## Net Configuration Tab

The **Net Configuration tab** in the Training dialog allows you to select the type of neural network that will be trained on your data. You may select a specific net configuration or select a **Best Net** search where NeuralTools will test a variety of possible configurations to identify the best performing one for you.

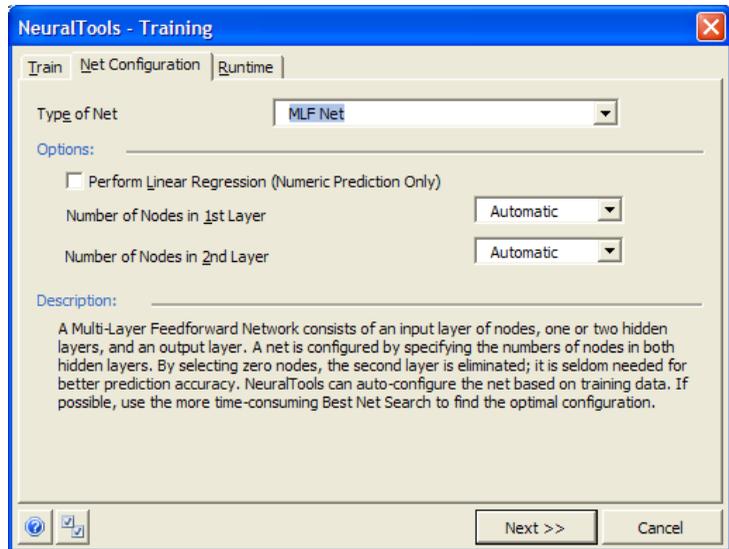
NeuralTools supports different neural network configurations to give the best possible predictions. For classification/category prediction, two types of networks are available: **Probabilistic Neural Networks (PNN)** and **Multi-Layer Feedforward Networks (MLF)**. Numeric prediction can be performed using MLF networks, as well as **Generalized Regression Neural Networks (GRNN)**, which are closely related to PNN networks. For more information on the technical aspects of the available network configurations, see the **More on Neural Networks** section.



The **Net Configuration tab** includes the following:

- **Type of Net** – Selects the type of net to be used in training, or alternatively, selects a Best Net search. The Net Configuration tab **Options** change depending on the type of net selected. Available net types are:
  - 1) **Best Net Search.** In a Best Net Search, NeuralTools tests all checked net configurations, including PNN/GRNN and MLFN nets with node counts in the entered minimum-maximum range. The best performing configuration for your data is identified based on the error obtained on the testing data. If **Store All Trial Nets in New Workbook** is selected, you will be able to individually load each tested net (regardless if it was the best performing network) from a workbook and use it for prediction after training is done; a full testing Summary Report for each net will also be available.

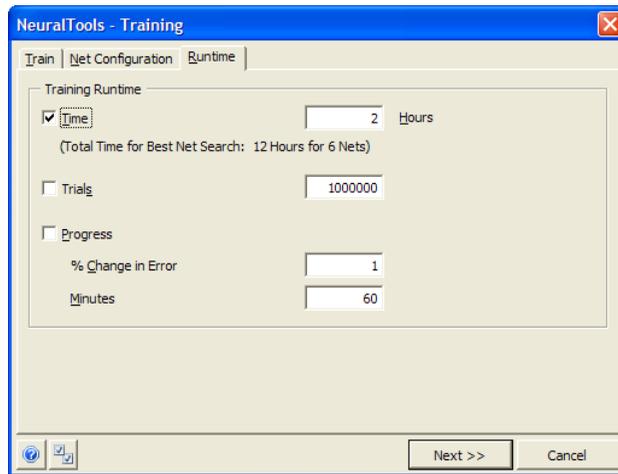
- 2) **PNN/GRNN Net.** These net types require no additional options to be selected for training; for this reason this setting is the default when NeuralTools is installed. If your data has numeric output values a GRNN network will be trained and if your data has categorical output values a PNN network will be trained.
- 3) **MLFN Net.** A Multi-Layer Feedforward Network (MLFN) has one or two hidden layers of nodes.



By selecting zero nodes for the second layer it will be eliminated. The most reliable way to find the best configuration of an MLFN net is to use the Best Net Search option instead of the option to train a single MLFN net. If there is not enough time for Best Net Search, it is recommended that the "Number of Nodes" values be left as "Automatic".

## Runtime Tab

The **Runtime tab** in the Training dialog allows you to enter stopping conditions for training. If no stopping conditions are selected, training will stop eventually; that period will be relatively short for PNN/GRNN nets, and much longer with MLF nets. One possible approach is to select no stopping conditions and click the Stop button in the training progress dialog when no more time is available for training. With Best Net Search a time limit for training a single net must be defined, to ensure that the search algorithm does not devote too much time to one particular configuration. The three available stopping conditions can be combined, specifying that NeuralTools will stop when any of the conditions are reached.



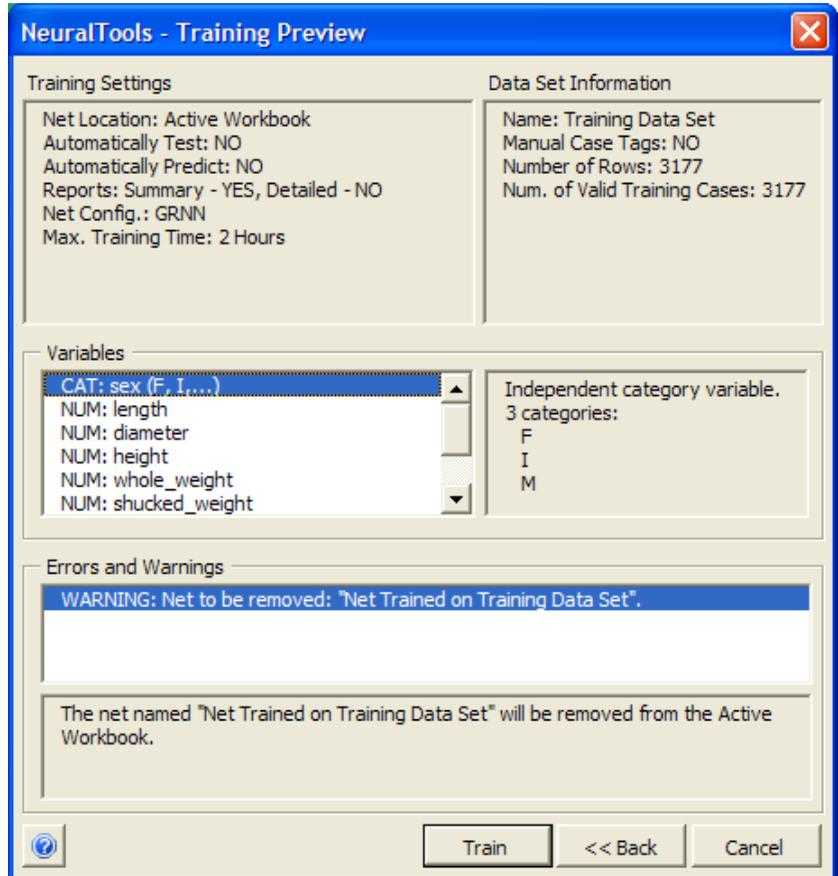
The Training Runtime options include:

- **Time** – Specifies a fixed time limit for training a single network. Training may stop before the specified period elapses, as soon as the algorithm determines that it is unlikely that further progress will be made. If a Best Net search is used, each tested net configuration will train for the entered time.
- **Trials** – Specifies that NeuralTools will execute no more than the specified number of trials before stopping. With Multi-Layer Feedforward Networks, a "trial" is a single assignment of "weights" to connections between neurons; training consists of an intelligent search for weights that will generate best predictions. With Probabilistic Neural Nets and Generalized Regression Neural Nets, a trial is an assignment of "smoothing factors" to variables. Training consists of a search for best smoothing factors.

- **Progress** – Specifies that NeuralTools will stop if it cannot improve the error statistic at least the entered % with the specified timeframe.

**Training  
Preview Dialog**

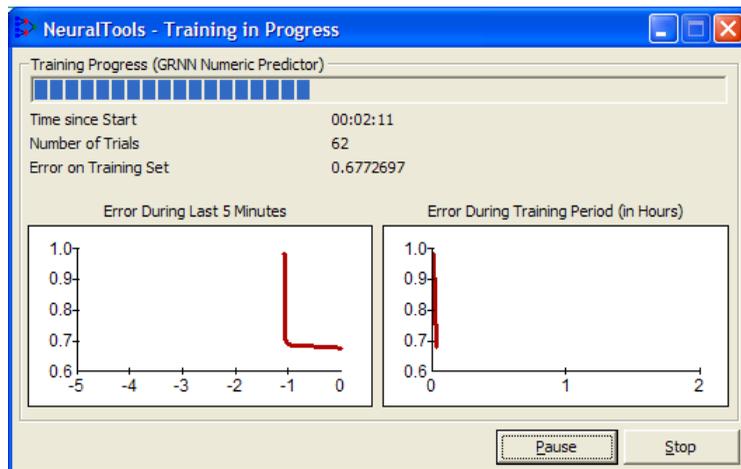
The Training Preview dialog shows the setup of the current network training along with any errors detected in your data, prior to starting training. By examining the contents of this dialog, you can see all your selected training assumptions as reported by NeuralTools. The **Errors and Warnings** section gives a description of any problems NeuralTools has detected in your data or settings which you can correct if necessary prior to spending time training.



## Training Progress Window

The Training Progress window reports on the status of network training as it runs. Graphs detail how NeuralTools is doing at improving the network and reducing the reported error.

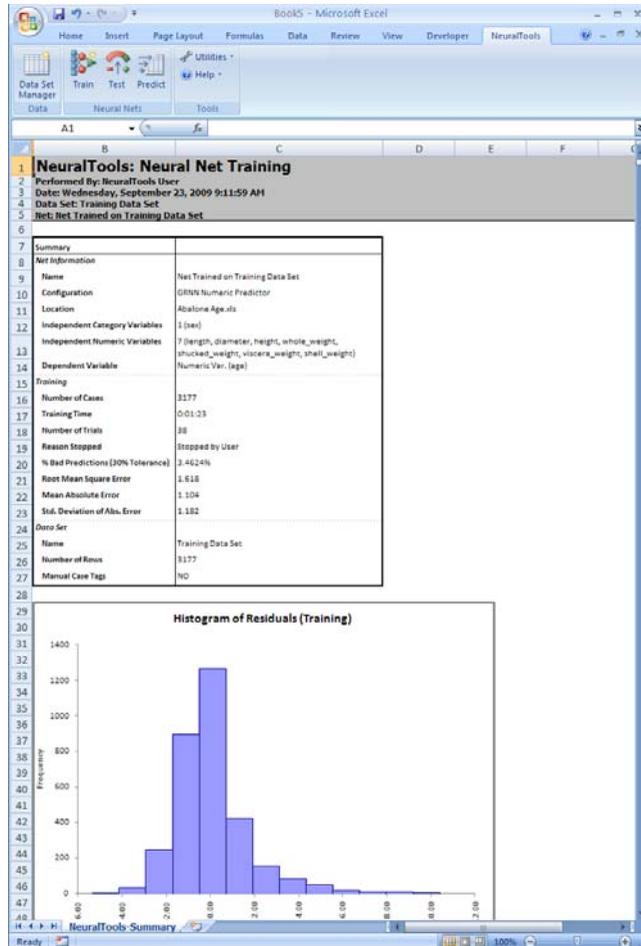
The Training Progress Window reports error on the training data. Observing changes in this value should not lead to any direct conclusions about the quality of predictions the net will make for cases not used in training. Such conclusions should be based on the error obtained on the testing data. Also note that with numeric prediction the error reported in the Progress Window is the Root Mean Square error based on scaled data (see information about scaling in "Inputs Transformation" section). For category prediction the reported error is based on numeric representation of category data.



## Training Reports

Both summary and detail reports can be created after training. These reports detail the performance of the trained neural network. The actual contents of the generated reports are specified in the Application Settings dialog, under the Reports to Generate and Columns in Detailed Reports settings.

- **Training Summary Report** – The training summary report gives statistics and graphs on the performance of the trained neural net.



For Category Prediction/ Classification, key statistics and graphs in the training summary report include:

- 1) **% Bad Predictions** - the percent of cases for which the predicted category does not agree with the actual category.

- 2) **Mean Incorrect Probability (available with PNN nets only)** - for every case, NeuralTools computes Probability of Incorrect Categories, which is the sum of probabilities assigned by PNN net to incorrect categories. For example, if for a given case a net assigns 30% probability to red, 20% to yellow, and 50% to green, and we know that the correct answer is red, then the value for that case is  $20\% + 50\% = 70\%$ . This value provides a case-by-case error measure for category prediction, corresponding to the Residual Error for numeric prediction. "Mean Incorrect Probability" is the average error value for all the cases.

Detailed Reports show Incorrect Probability on a case-by-case basis, and to better understand the concept it may be helpful to change Detailed Report settings to show the probabilities assigned by a Probabilistic Neural Net to every possible category for the dependent variable. To do that, select **Application Settings** in the **Utilities** menu, and click the drop-down menu at the right of the **Columns in Detailed Reports** row. The **NeuralTools - Columns to Display in Detailed Reports** dialog will display. In that dialog select **Probabilities of All Categories (for PNN)** for Testing. Then train a PN Net on a data set with at least 3 categories in the dependent variable (the Auto Loans.xls example file can be used) with **Automatically Test** selected. In the resulting Detailed Report, observe how the values in the **Incorrect%** column relate to the probabilities assigned to each possible category; the Incorrect% is the sum of the probabilities for all incorrect categories.

- 3) **Classification Matrix** - compares actual to predicted categories on category-by-category basis. For example, classification matrix may reveal that a net correctly detects a medical condition in patients that have it, but has some tendency to raise false alarms for healthy patients.
- 4) **Variable Impacts** - (if selected) displays the relative impact of independent variables on predicted answers.
- 5) **Histogram of Probability of Incorrect Categories** (available with PNN nets only) - see "Mean Incorrect Probability" above for explanation of "Probability of Incorrect Categories".

For Numeric Prediction, key statistics and graphs in the training summary report include:

- 1) **% Bad Predictions** - a prediction counts as "bad" if it falls outside the defined margin around the actual value; the width of the margin is defined as 'Good/Bad Tolerance (Training)' setting in the Application Settings dialog.
- 2) **Root Mean Square Error** - a measure of deviation of predictions from actual value (calculated as square root of average square deviation).
- 3) **Mean Absolute Error** - average deviation of predictions from actual values.
- 4) **Variable Impacts** - (if selected) displays the relative impact of independent variables on predicted answers.
- 5) **Histogram of Residuals** - "residual" is the difference between the actual and the predicted value.
- 6) **Scatter plots** showing relationships between actual values, predicted values, and residuals.

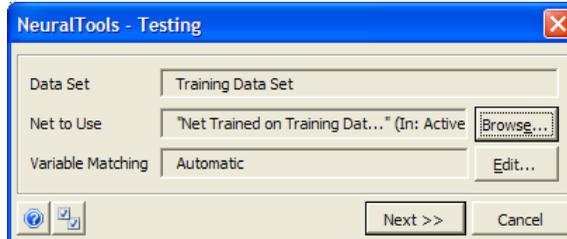
## Test Command

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### Specifies settings for testing a trained neural network and runs the testing

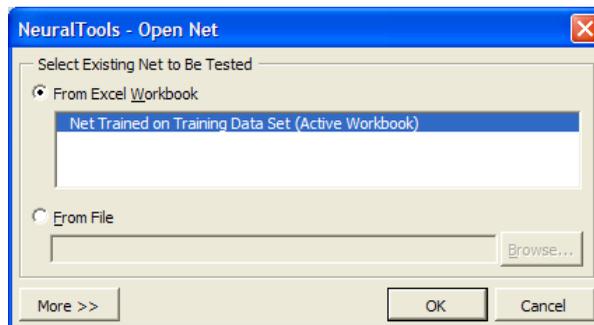
---

The **Test** command allows you to 1) specify settings to be used for testing a trained neural network and then 2) start the testing.



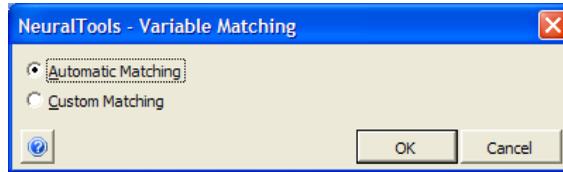
Testing data usually is data with known output values that were not used in training the net. Options in the Testing dialog include:

- **Data Set** – shows the data set to be used when testing the trained neural network. This data set needs to be defined using the Data Set Manager and be present in the active worksheet.
- **Net to Use** – specifies the name and location for the neural net to be tested. Neural networks may be saved to an Excel workbook or to a file on disk. Click **Browse...** to change the name or location shown.



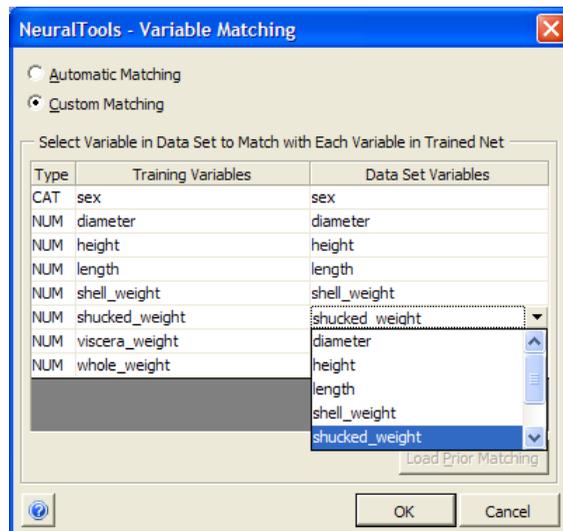
## Variable Matching

**Variable Matching** specifies how variables in the data set to be tested will be matched with variables in the data set that was used to train the net.



Two options are possible for variable matching:

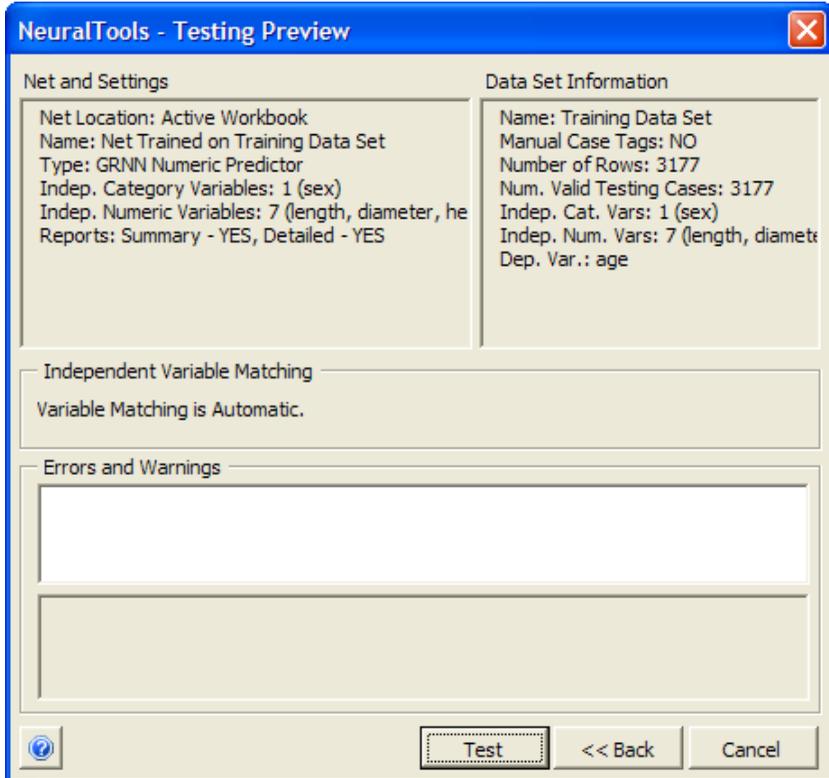
- 1) **Automatic Matching.** Variable Names in the testing data set are matched by name with those in the trained net's data set, and variable types are set based on this matching
- 2) **Custom Matching.** Custom matching allows you to individually assign the matching of variables in the testing data set with those in the trained net's data set. This is done when variable names are different in the two data sets or different assignments are desired.



The Variable Matching dialog lists the names of variables in each data set so they can be matched. Only variables with the same type may be matched. Each time you do a matching, the assignments made are stored with the data set. By clicking **Load Prior Matching**, you can cycle through previously-made matchings to access a set of previous assignments for the data set.

## Testing Preview Dialog

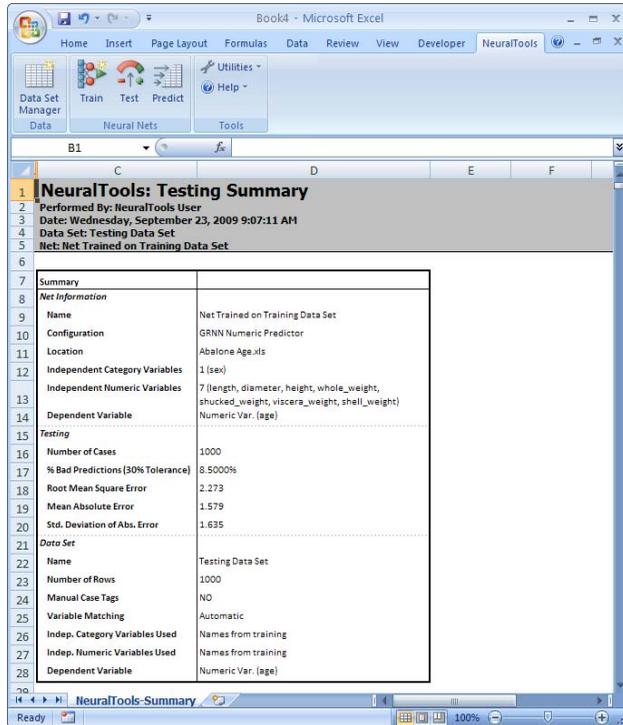
The Testing Preview dialog shows the setup of the current network testing along with any errors detected in your data, prior to starting testing. By examining the contents of this dialog, you can see all your selected testing assumptions as reported by NeuralTools. The **Errors and Warnings** section gives a description of any problems NeuralTools has detected in your data which you can correct if necessary prior to testing.



## Testing Reports

Both summary and detail reports can be created after testing. These reports detail the performance of the trained neural network on the test data set. The actual contents of the generated reports are specified in the **Application Settings** dialog, under the **Reports to Generate** and **Columns in Detailed Reports** settings. The detailed report is especially useful when testing as it shows how the trained net did at predicting individual output values in the test data set.

- **Testing Summary Report** – The testing summary report gives statistics and graphs on the performance of the trained neural net on the test data set.



NeuralTools: Testing Summary	
Performed By: NeuralTools User	
Date: Wednesday, September 23, 2009 9:07:11 AM	
Data Set: Testing Data Set	
Net: Net Trained on Training Data Set	
Summary	
Net Information	
Name	Net Trained on Training Data Set
Configuration	GRNN Numeric Predictor
Location	Abalone Age.xls
Independent Category Variables	1 (sex)
Independent Numeric Variables	7 (length, diameter, height, whole_weight, shucked_weight, viscera_weight, shell_weight)
Dependent Variable	Numeric Var. (age)
Testing	
Number of Cases	1000
% Bad Predictions (30% Tolerance)	8.5000%
Root Mean Square Error	2.273
Mean Absolute Error	1.579
Std. Deviation of Abs. Error	1.635
Data Set	
Name	Testing Data Set
Number of Rows	1000
Manual Case Tags	NO
Variable Matching	Automatic
Indep. Category Variables Used	Names from training
Indep. Numeric Variables Used	Names from training
Dependent Variable	Numeric Var. (age)

For Category Prediction, key statistics and graphs in the testing summary report include:

- 1) **% Bad Predictions** - the percent of cases for which the predicted category does not agree with the actual category.
- 2) **Mean Incorrect Probability** (available with PNN nets only) - for every case, NeuralTools computes Probability of Incorrect Categories, which is the sum of probabilities assigned by PNN net to incorrect categories. For example, if for a given case a net assigns 30% probability to red, 20% to yellow, and 50% to green, and we know

that the correct answer is red, then the value for that case is  $20\% + 50\% = 70\%$ . This value provides a case by case error measure for category prediction, corresponding to the Residual Error for numeric prediction. "Mean Incorrect Probability" is the average error value for all the cases.

Detailed Reports show Incorrect Probability on a case-by-case basis, and to better understand the concept it may be helpful to change Detailed Report settings to show the probabilities assigned by a Probabilistic Neural Net to every possible category for the dependent variable. To do that, select **Application Settings** in the **Utilities** menu, and click the drop-down menu at the right of the **Columns in Detailed Reports** row. The **NeuralTools - Columns to Display in Detailed Reports** dialog will display. In that dialog select **Probabilities of All Categories (for PNN)** for Testing. Then train a PN Net on a data set with at least 3 categories in the dependent variable (the Auto Loans.xls example file can be used) with **Automatically Test** selected. In the resulting Detailed Report, observe how the values in the **Incorrect%** column relate to the probabilities assigned to each possible category; the Incorrect% is the sum of the probabilities for all incorrect categories.

- 3) **Classification Matrix** - compares actual to predicted categories on category-by-category basis. For example, classification matrix may reveal that a net correctly detects a medical condition in patients that have it, but has some tendency to raise false alarms for healthy patients.
- 4) **Histogram of Probability of Incorrect Categories** (available with PNN nets only) - see "Mean Incorrect Probability" above for explanation of "Probability of Incorrect Categories".

For Numeric Prediction, key statistics and graphs in the testing summary report include:

- 1) **% Bad Predictions** - a prediction counts as "bad" if it falls outside the defined margin around the actual value; the width of the margin is defined in the 'Good/Bad Tolerance (Testing)' setting in the Application Settings dialog.
- 2) **Root Mean Square Error** - a measure of deviation of predictions from actual value (calculated as square root of average square deviation).
- 3) **Mean Absolute Error** - average deviation of predictions from actual values.
- 4) **Histogram of Residuals** - "residual" is the difference between the actual and the predicted value.
- 5) **Scatter plots** showing relationships between actual values, predicted values, and residuals.

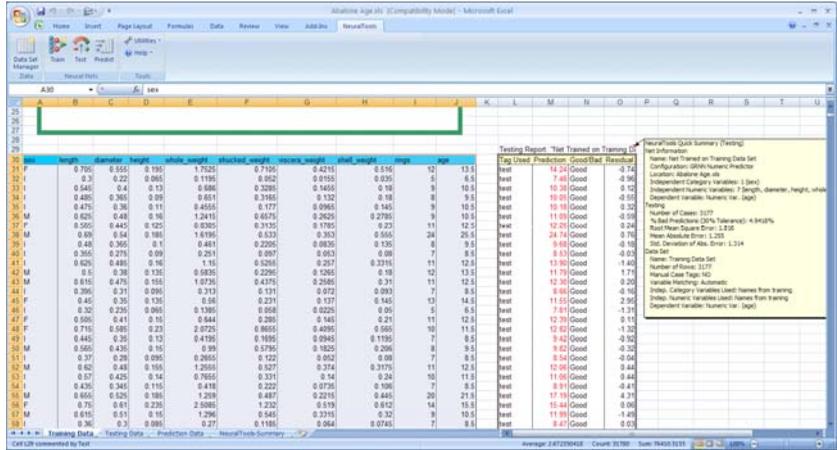
- **Testing Detailed Report.** This report is placed next to the testing data set and shows how the trained net did at predicting individual output values in the test data set.

sex	length	diameter	height	whole_weight	shucked_weight	viscera_weight	shell_weight	rings	age	Tag Used	Prediction	Good/Bad	Residual
31 F	0.705	0.555	0.195	1.7529	0.7105	0.4215	0.516	12	13.5	test	14.24	Good	-0.74
32 I	0.3	0.22	0.065	0.1195	0.052	0.0155	0.035	5	6.5	test	7.45	Good	-0.95
33 I	0.545	0.4	0.13	0.686	0.2095	0.1455	0.18	9	10.5	test	10.38	Good	0.12
34 I	0.485	0.365	0.09	0.651	0.3165	0.132	0.18	8	9.5	test	10.05	Good	-0.55
35 I	0.475	0.36	0.11	0.4555	0.177	0.0965	0.145	9	10.5	test	10.18	Good	0.32
36 M	0.625	0.48	0.16	1.2415	0.6375	0.2625	0.2785	9	10.5	test	11.09	Good	-0.59
37 F	0.565	0.445	0.125	0.8305	0.3135	0.1785	0.23	11	12.5	test	12.26	Good	0.24
38 M	0.69	0.54	0.185	1.6195	0.533	0.353	0.555	24	25.5	test	24.74	Good	0.76
39 I	0.48	0.365	0.1	0.461	0.2205	0.0835	0.135	8	9.5	test	9.68	Good	-0.18
40 I	0.255	0.275	0.09	0.251	0.097	0.053	0.08	7	8.5	test	8.53	Good	-0.03
41 I	0.625	0.485	0.16	1.15	0.5255	0.257	0.3315	11	12.5	test	13.90	Good	-1.40
42 M	0.5	0.38	0.135	0.5835	0.2295	0.1265	0.18	12	13.5	test	11.79	Good	1.71
43 M	0.615	0.475	0.155	1.0735	0.4375	0.2585	0.31	11	12.5	test	12.30	Good	0.20
44 I	0.295	0.31	0.095	0.313	0.131	0.072	0.093	7	8.5	test	8.66	Good	-0.16
45 F	0.45	0.35	0.135	0.56	0.231	0.137	0.145	13	14.5	test	11.55	Good	2.95
46 I	0.32	0.235	0.065	0.1385	0.058	0.0225	0.05	5	6.5	test	7.81	Good	-1.31
47 F	0.505	0.41	0.15	0.644	0.285	0.145	0.21	11	12.5	test	12.39	Good	0.11
48 F	0.715	0.585	0.23	2.0725	0.8655	0.4095	0.565	10	11.5	test	12.82	Good	-1.32
49 I	0.445	0.35	0.13	0.4195	0.1695	0.0945	0.1195	7	8.5	test	9.42	Good	-0.92
50 M	0.565	0.435	0.15	0.99	0.5795	0.1825	0.206	8	9.5	test	9.82	Good	-0.32
51 I	0.37	0.28	0.095	0.2655	0.122	0.052	0.08	7	8.5	test	8.54	Good	0.04
52 M	0.62	0.48	0.155	1.2555	0.527	0.374	0.3175	11	12.5	test	12.06	Good	0.44
53 I	0.57	0.425	0.14	0.7655	0.331	0.14	0.24	10	11.5	test	11.06	Good	0.44
54 I	0.435	0.345	0.115	0.418	0.222	0.0735	0.106	7	8.5	test	8.91	Good	-0.41
55 M	0.655	0.525	0.185	1.259	0.487	0.2215	0.445	20	21.5	test	17.16	Good	4.31
56 F	0.75	0.61	0.235	2.5085	1.232	0.919	0.92	14	15.5	test	15.44	Good	0.06
57 M	0.615	0.51	0.15	1.296	0.545	0.3315	0.32	9	10.5	test	11.99	Good	-1.49
58 I	0.36	0.3	0.085	0.27	0.1185	0.064	0.0745	7	8.5	test	8.47	Good	0.03
59 M	0.155	0.11	0.04	0.0155	0.0065	0.003	0.005	3	4.5	test	5.40	Good	-1.10
60 I	0.44	0.335	0.11	0.3885	0.175	0.0935	0.111	7	8.5	test	9.02	Good	-0.52

In the Testing Detailed Report, predictions are marked as "Good" or "Bad" based on the tolerance level set in the Application Settings dialog. If you are running multiple tests, Detailed Reports may be added in new columns to the right of the test data set, so you can see how predictions change for individual cases as new trained nets are tested.

**Quick  
Summaries in  
Detailed  
Reports**

A popup comment in Excel provides quick access to Summary Report information while examining a Detailed Report. Simply roll the mouse over the report header and the popup comment will be displayed. Note - Comments must be enabled in the **Excel Tools Command Options Dialog View tab** for popup comments to be displayed.



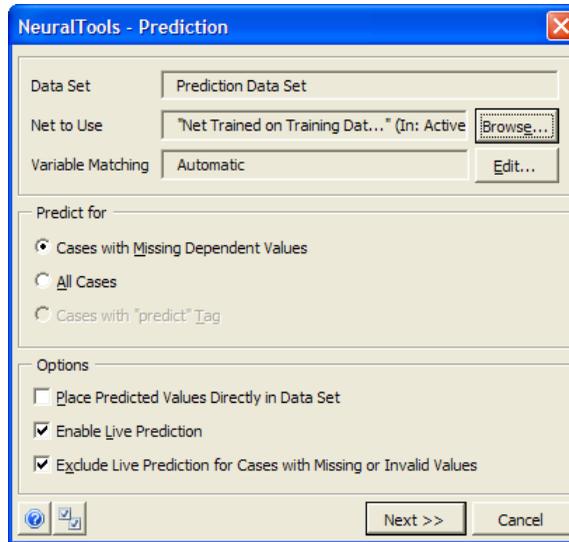
## Predict Command

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**Specifies settings for predicting values using a trained neural network and runs the prediction**

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The **Predict** command allows you to 1) specify settings to be used for predicting values using a trained neural network and then 2) run the prediction.



Data to predict typically are cases with unknown dependent variable values. Options in the Testing dialog include:

- **Data Set** – shows the data set to be used for prediction. This data set needs to be defined using the Data Set Manager and be present in the active worksheet.
- **Net to Use** – specifies the name and location for the neural net to be used for prediction. Neural networks may be saved to an Excel workbook or to a file on disk. Click **Browse...** to change the name or location shown.
- **Variable Matching** – Specifies how variables in the data set with the prediction data will be matched with variables in the data set that was used to train the net. Click **Edit...** to change variable matching. For more information on **Variable Matching**, see the **Test** command in this chapter.

- **Predict For** – Selects the cases for which predictions will be made. Typically you will select to predict cases with **Missing Dependent Variable Values**, but you can make prediction for **All Cases** (even those where the dependent variable value is known) if desired. If you have a Tag variable in the data set, dependent variable values will be predicted only for cases marked with the Tag "predict".
- **Options** – sets predicted value location and Live Prediction options.
  - 1) **Place Predicted Values Directly in Data Set.** This option specifies that predicted values will be placed directly in the dependent variable location in the data set for each predicted case, possibly in addition to being placed in the Detailed Report (depending on whether Detailed Reports are selected in the Reports to Generate setting in Application Settings). This overwrites any current contents of the cell so should be used with caution. You will be able to identify predicted values by color in the data set.
  - 2) **Enable Live Prediction** - specifies that NeuralTools will place formulas in the cells where the predicted dependent variable values are shown. These formulas allow NeuralTools to calculate the predicted values as independent values change.
  - 3) **Exclude Live Prediction for Cases with Missing or Invalid Values** – specifies that a live prediction formula will not be added where input variable values for a case are missing. Missing input values cause live prediction formulas to return an error value. However, it may be useful to allow NeuralTools to enter formulas in cases where independent values are missing, because as soon as missing values are filled, the prediction will automatically show.

## **Live Prediction**

**Live Prediction** is a powerful capability of NeuralTools (Industrial version only) that allows you to perform predictions automatically in Excel without going through a specific Predict operation. With Live Prediction, NeuralTools places formulas in the cells where the predicted dependent variable values are shown. These formulas use a custom NeuralTools function to calculate the predicted values, such as:

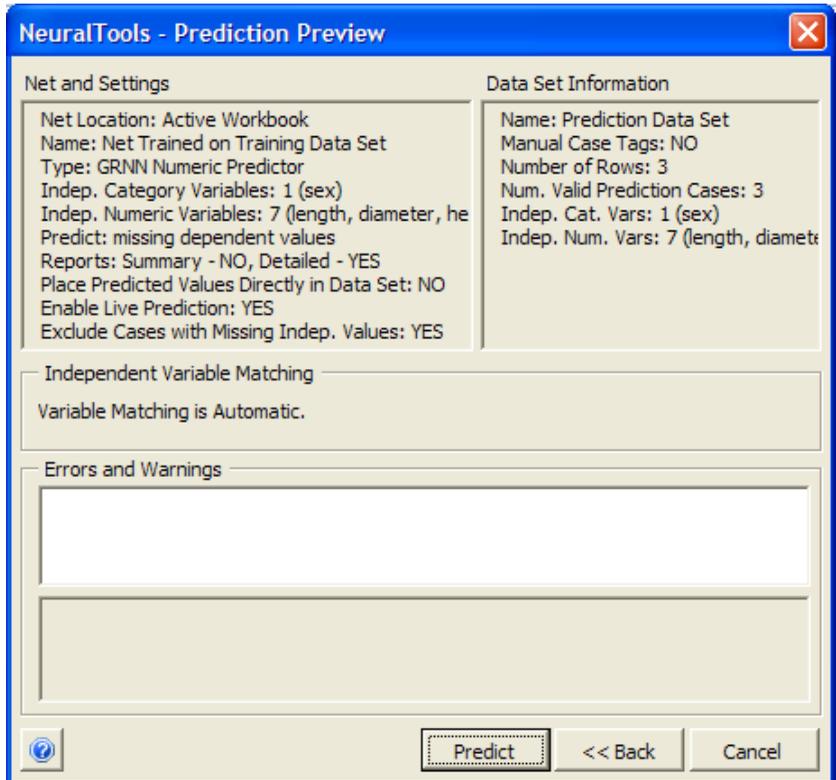
```
=NetOutputPrediction(_PALDS_DG25B8C82B!$A$140,  
"DG25B8C82B", "VG1DD83AF2", 'Prediction Data'!$A$6:$I$6,  
A7:I7)
```

The actual formula is added to your worksheet by NeuralTools and does not need to be entered by you. The arguments let NeuralTools identify the trained network in use, along with the location of the independent values in the worksheet. When the input independent variable values for a case are added or changed, NeuralTools will automatically return a new predicted value. This makes it simple to add and generate predictions for new cases using an existing trained net.

Note: if the prediction will be based on cell values that are not expected to change, then de-selecting Live Prediction in training or prediction dialog is recommended; this will minimize the time it takes for Excel to recalculate the workbook.

**Prediction  
Preview Dialog**

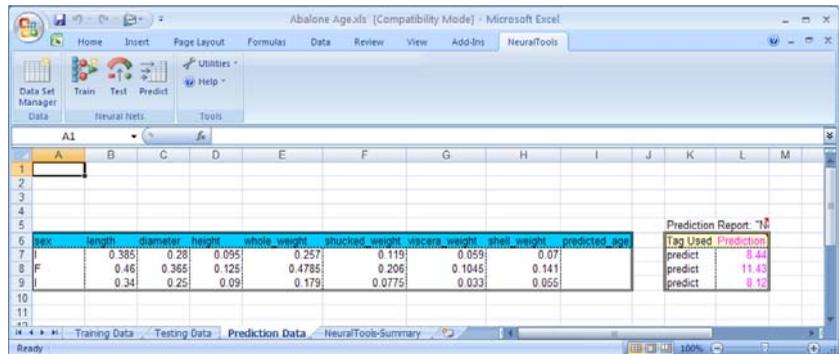
The Prediction Preview dialog shows the prediction setup for the selected data set along with any errors detected in your data or settings, prior to starting prediction. By examining the contents of this dialog, you can see all your selected prediction assumptions as reported by NeuralTools. The **Errors and Warnings** section gives a description of any problems NeuralTools has detected in your data which you can correct if necessary prior to prediction.



## Prediction Reports

Both summary and detail reports can be created after prediction. These reports detail the performance of the trained neural network on the test data set. The actual contents of the generated reports are specified in the **Application Settings** dialog, under the **Reports to Generate** and **Columns in Detailed Reports** settings.

- **Prediction Detailed Report.** This report is placed next to the prediction data set. It provides a location for predictions when the user does not want to place them inside the dependent variable in the data set itself; if the dependent variable contains historical data for some cases, it may be safer to not mix those historical cases with net predictions.



The screenshot shows a Microsoft Excel spreadsheet with the following data:

sex	length	diameter	height	whole_weight	shucked_weight	viscera_weight	shell_weight	predicted_age
I	0.385	0.28	0.095	0.257	0.119	0.059	0.07	
F	0.46	0.365	0.125	0.4785	0.206	0.1045	0.141	
I	0.34	0.25	0.09	0.179	0.0775	0.033	0.055	

The Prediction Report is shown in a separate table to the right:

Tag Used	Prediction
predict	8.44
predict	11.43
predict	8.12

If you are running multiple predictions, Detailed Reports may be added in new columns to the right of the data set, so you can see how predictions change for individual cases as new trained nets are used.

# Utilities

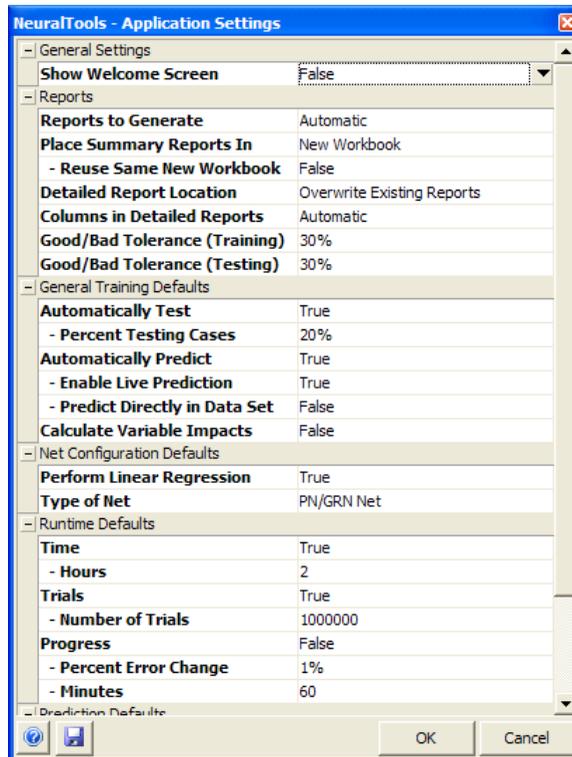
## Application Settings Command

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### Specifies default settings for training, testing and prediction

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The **Application Settings** command allows you to select 1) which reports to generate for training, testing and prediction, 2) what Training defaults to use and 3) what Prediction and Runtime defaults to use. Many Application Settings are defaults to be used in the Training, Testing or Prediction dialogs. See the description of those dialogs to get more information on those settings. Other settings are covered here.

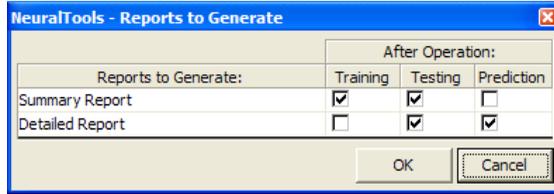


### Reports

Reports settings include:

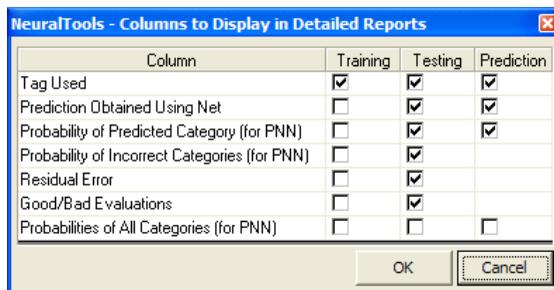
- **Reports to Generate** - Each operation in NeuralTools can produce both a summary and a detailed report. However, typically you will want to use the default report setting as certain reports add little value to certain operations. For

example, the Detailed report is the standard report from Prediction, and a Summary report in this case adds little value.



Summary Reports are placed on their own worksheet, while Detailed Reports are placed in columns to the right of a data set, in the same worksheet as the data set.

- **Place Summary Reports in** options include:
  - **New Worksheet** where a new worksheet is created for each report. You may reuse the same workbook for your reports or always create a new workbook.
- **Detailed Report Location** options include:
  - **Overwrite Existing Reports**, where columns with data from prior Detailed Reports in a data set are overwritten with new Detailed Reports (to delete a Detailed Report manually, select entire columns containing it by clicking and dragging over column headers, then select Delete from the Edit menu).
  - **Right of the Data Set** where new columns are inserted to the right of the data set to hold the new Detailed Reports.
  - **Right of Existing Reports** where columns to the right of the data set and existing reports are used to hold the new Detailed Reports.
- **Columns to Display in Detailed Reports.** For every selected row, a column will be displayed in the Detailed Report to the right of the data set that will show the information for every case.



The following columns can be displayed:

- 1) **Tag Used** - "train", "test" and "predict" tags show for every case if it was used as part of the training or testing set, or whether a prediction was made for a given case.
  - 2) **Prediction Obtained Using Net** - Number or category predicted by net.
  - 3) **Probability of Predicted Category (for PNN)** - Probabilistic Neural Nets not only predict an unknown category, but also assign a probability of that category. Not available when categories are predicted using Multi-Layer Feedforward Networks. Does not apply to numeric prediction.
  - 4) **Probability of Incorrect Categories (for PNN)** - Sum of probabilities assigned by a PNN net to incorrect categories. For example, if for a given case a net assigns 30% probability to red, 20% to yellow, and 50% to green, and we know that the correct answer is red, then the value for that case is  $20\% + 50\% = 70\%$ . This column provides a case-by-case error measure for category prediction, corresponding to the "Residual Error" column for numeric prediction.
  - 5) **Residual Error** - The difference between the actual and the predicted dependent value. Does not apply to category prediction.
  - 6) **Good/Bad Evaluation** - For numeric prediction, the column states if the prediction for a given case falls within the defined margin around the actual value; the width of the margin is defined as "Tolerance for Good/Bad Evaluation". For category prediction, the column simply states if the predicted category agrees with the actual one.
  - 7) **Probabilities of All Categories (for PNN)** - If this option is selected and a Probabilistic Neural Net is trained, one column will be inserted for every dependent category. For example, if the net is used to predict a color, there may be "red%", "yellow%", and "green%" columns, containing probabilities assigned to each color.
- **Tolerance for Good/ Bad Evaluation.** For testing and training, if a numeric prediction is within the entered % of the actual dependent variable value, it will be labeled as "Good".

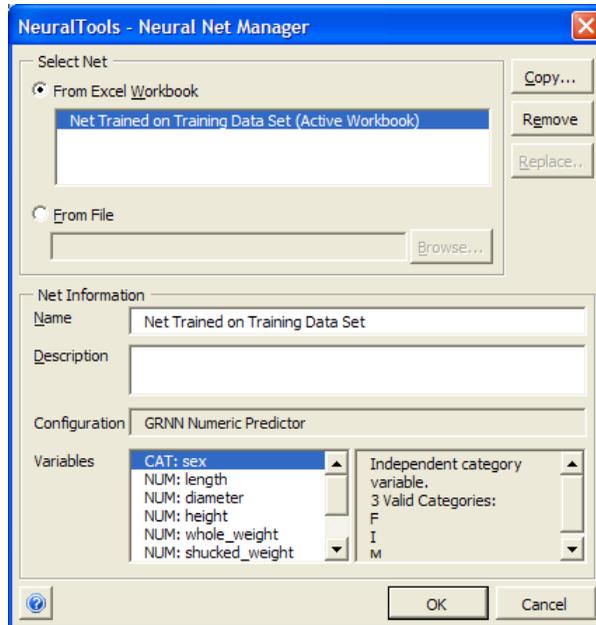
## Neural Net Manager Command

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**Allows the copying, moving and deletion of trained neural networks**

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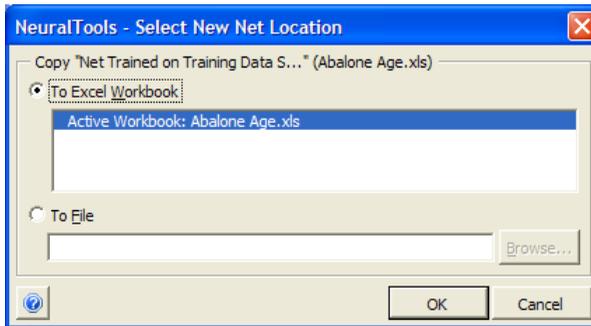
The Neural Net Manager Command allows you to manage trained neural networks, moving them between workbooks and files as well as adding descriptive information to them.



Neural networks can be stored in an Excel workbook or in a file on disk. Any number of networks may be placed in a single Excel workbook. Using the Neural Net Manager you can move networks to new workbooks or files, or delete or replace them. This allows you to easily analyze data sets in other workbooks using existing trained networks, without the workbook with the training data present.

Neural Net Manager options include:

- **Copy** – This copies a trained neural network to a different location. Simply select the workbook or file where you wish to place the network.



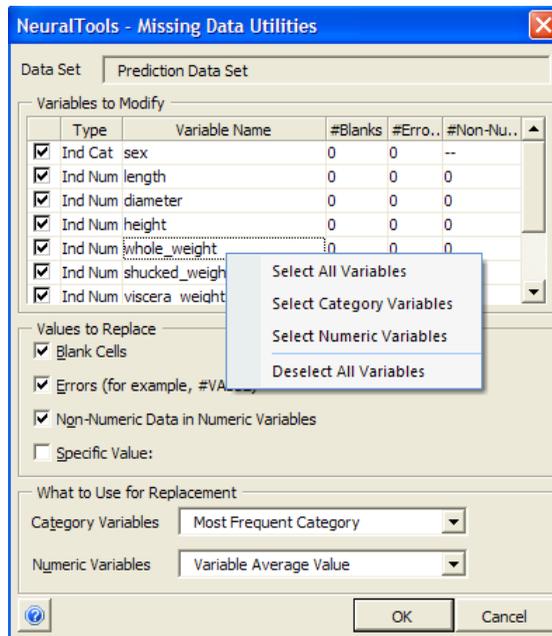
- **Remove** – Deletes a trained neural network.
- **Replace** – Overwrites a trained neural network with a new one. This feature is available with nets that are used for Live Prediction. After replacement, live predictions that were previously made using the old net will be made using the new one. This, however, does not apply to Detailed Reports. If a detailed report contains live prediction cells where the net to be replaced is used, then after replacement those cells will contain fixed values.
- **Net Information** – Allows descriptive information to be added to a network. This helps identify the trained network and the conditions it was trained under.

# Missing Data Utilities Command

**Allows the replacement of missing data and error values in a data set with artificial values**

The Missing Data Utilities command allows you to replace missing or other unwanted data in your data set with artificial values. Cases with missing variable values are disregarded by NeuralTools during training, testing and prediction, so it is often useful to correct these prior to processing.

The Training Preview dialog box will give you a warning when you have cases with missing values in a data set. If this happens, these cases can be fixed using the Missing Data Utilities command.



The Missing Data Utilities dialog has the following options:

- **Variables to Modify** - Provides a list of the variables used in the data set in the current worksheet and displays the number missing, error and (for numeric variables) non-numeric data. Checking a variable selects it to have missing or other unwanted data replaced.

The variable list provides a right-click menu with commands for selecting and deselecting groups of variables.

- **Values to Replace** – Selects the types of values in the selected variables that will be replaced. **Specific Value** allows you to replace all instances of a specific value for a variable with a new value.
- **What to Use For Replacement** – Specifies the values to be placed in the data set instead of the missing or other unwanted data. Different values are specified for Category and Numeric variables:

**Category Variables** – Options are:

- **Most or Least Frequent Category** – the category value that occurs most or least frequently for cases in the data set
- **Neighboring Category** – the category value that occurs in the case in the data set next to the case with the missing value
- **Randomly Selected Category** – a category value randomly selected from those in the data set
- **Specific Category** – sets all missing or unwanted values to a specific value

**Numeric Variables** – Options are:

- **Variable Average Value** – the average value for the variable across all cases in the data set
- **Variable Median Value** – the median value for the variable across all cases in the data set
- **Interpolation from Neighboring Values** – the value calculated by interpolating between the variable values in the cases in the data set next to the case with the missing value
- **Random Val. (between Min. and Max.)** – a random value selected between the variable minimum and maximum for all cases in the data set

For both variable types, **Clear Cells** clears the selected values for the variable.

## ***More on Missing Values***

The Missing Data Utilities dialog provides one possible approach to missing data: it generates artificial data where actual data is missing. It may often be better to simply leave missing data as blank cells, and let NeuralTools disregard cases with missing data. Note that NeuralTools will not recognize special symbols like "?" as missing data; question marks need to be cleared, and this can be accomplished with the Missing Data Utilities, by selecting "Specific Value" in Values to Replace section, and "Clear Cells" in "What to Use for Replacement" section.

It may also be possible to use NeuralTools to predict missing values in one independent variable from other independent variables that have little or no missing data. Testing results will indicate if a net trained to predict missing values is reliable.

---

# More on Neural Networks

## Neural Network Basics

A neural network is a system that takes numeric inputs, performs computations on these inputs, and outputs one or more numeric values. When a neural net is designed and trained for a specific application, it outputs approximately correct values for given inputs. For example, a net could have inputs representing some easily measured characteristics of an abalone (a sea animal), such as length, diameter and weight. The computations performed inside the net would result in a single number, which is generally close to the age of the animal (the age of an abalone is harder to determine).

The inspiration for neural nets comes from the structure of the brain. A brain consists of a large number of cells, referred to as "neurons". A neuron receives impulses from other neurons through a number of "dendrites". Depending on the impulses received, a neuron may send a signal to other neurons, through its single "axon", which connects to dendrites of other neurons. Like the brain, artificial neural nets consist of elements, each of which receives a number of inputs, and generates a single output, where the output is a relatively simple function of the inputs.

### Neural Nets vs. Statistical Methods

Neural nets provide an alternative to more traditional statistical methods. Like Linear Regression, they are used for function approximation. Like Discriminant Analysis and Logistic Regression, they are used for classification. The advantage of neural nets is that they are capable of modeling extremely complex functions. This stands in contrast with the traditional linear techniques (Linear Regression and Linear Discriminant Analysis). Techniques for optimizing linear models were well known before artificial neural nets were invented in middle of the 20th century. Effective algorithms for training neural nets took many years to develop. However, we now have a range of sophisticated algorithms for neural net training, making them an attractive alternative to the more traditional methods.

## The Structure of a Neural Net

The structure of a neural net consists of connected units referred to as "**nodes**" or "**neurons**". Each neuron performs a portion of the computations inside the net: a neuron takes some numbers as inputs, performs a relatively simple computation on these inputs, and returns an output. The output value of a neuron is passed on as one of the inputs for another neuron, except for neurons that generate the final output values of the entire system.

Neurons are arranged in **layers**. The input layer neurons receive the inputs for the computations, like the length, diameter, and weight of an individual abalone. These values are passed to the neurons in the first hidden layer, which perform computations on their inputs and pass their outputs to the next layer. This next layer could be another hidden layer, if there is one. The outputs from the neurons in the last hidden layer are passed to the neuron or neurons that generate the final outputs of the net, like the age of the abalone.

## Numeric and Category Prediction

When neural nets are used to predict numeric values, they typically have just one output. This is because single-output nets are more reliable than multiple-output nets, and almost any prediction problem can be addressed using single-output nets. For example, instead of constructing a single net to predict the volume and the price for a stock on the following day, it is better to build one net for price predictions, and one for volume predictions. On the other hand, neural nets have multiple outputs when used for classification/category prediction. For example, suppose that we want to predict if the price of a stock the following day will "rise more than 1%", "fall more than 1%", or "not change more than 1%". Then the net will have three numeric outputs, and the greatest output will indicate the category selected by the net.

## Training a Net

Training a net is the process of fine-tuning the parameters of the computation, where the purpose is to make the net output approximately correct values for given inputs. This process is guided by training data on the one hand, and the training algorithm on the other. The training algorithm selects various sets of computation parameters, and evaluates each set by applying the net to each training case to determine how good the answers given by the net are. Each set of parameters is a "trial"; the training algorithm selects new sets of parameters based on the results of previous trials.

## Computer Processing of Neural Nets

A neural net is a model of computations that can be implemented in various types of computer hardware. A neural net could be built from small processing elements, with each performing the work of a single neuron. However, neural nets are typically implemented on a computer with a single powerful processor, like most computers currently in use. With single-processor computers the program, like NeuralTools, uses the same processor to perform each neuron's computations; in this case the concept of a neuron describes part of the computations needed to obtain a prediction, as opposed to a physical processing element.

## Types of Neural Networks

There are various types of neural networks, differing in structure, kinds of computations performed inside neurons, and training algorithms. One type offered in NeuralTools is the **Multi-Layer Feedforward Network**. With MLF nets, a NeuralTools user can specify if there should be one or two layers of hidden neurons, and how many neurons the hidden layers should contain (NeuralTools provides help with making appropriate selections, as described in the section on MLF nets). NeuralTools also offers **Generalized Regression Neural Nets** and **Probabilistic Neural Nets**; these are closely related, with the former used for numeric prediction, and the latter for category prediction/classification. With GRN/PN nets there is no need for the user to make decisions about the structure of a net. These nets always have two hidden layers of neurons, with one neuron per training case in the first hidden layer, and the size of the second layer determined by some facts about training data.

The remaining sections of this chapter discuss in more detail each type of neural network offered in NeuralTools.

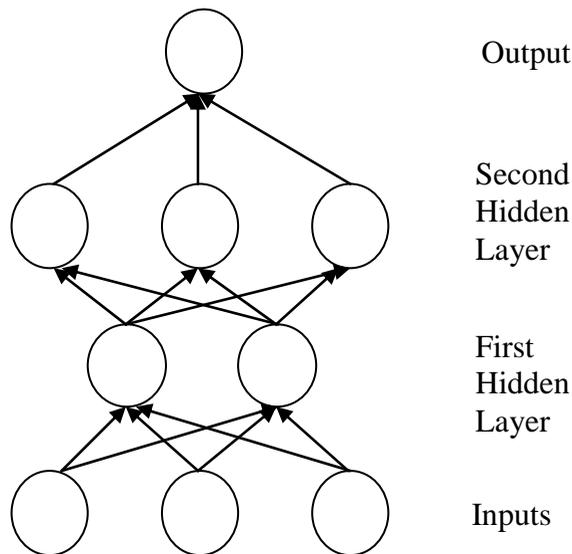


# Multi-Layer Feedforward Nets

Multi-Layer Feedforward Networks (also referred to as "Multi-Layer Perceptron Networks") are systems capable of approximating complex functions, and thus capable of modeling complex relationships between independent variables and a dependent one.

## MLF Architecture

The diagram below shows an MLF net for numeric prediction with three independent numeric variables; the net was configured to have 2 neurons/nodes in the first hidden layer, and 3 neurons/nodes in the second hidden layer.



The behavior of the net is determined by:

- Its topology (the number of hidden layers and the numbers of nodes in those layers)
- The "weights" of connections (a parameter assigned to each connection) and bias terms (a parameter assigned to each neuron)
- Activation/transfer function, used to convert the inputs of each neuron into its output

Specifically, a hidden neuron with  $n$  inputs first computes a weighted sum of its inputs:

$$Sum = in_0 * w_0 + in_1 * w_1 + \dots + in_n * w_n + bias$$

where  $in_0$  to  $in_n$  are outputs of neurons in the previous layer, while  $w_0$  to  $w_n$  are connection weights; each neuron has its own bias value. Then the activation function is applied to the  $Sum$  to generate the output of the neuron.

A sigmoid (s-shaped) function is used as the activation function in hidden layer neurons. Specifically, NeuralTools uses the hyperbolic tangent function. In NeuralTools the output neuron uses identity as the activation function; that is, it simply returns the weighted sum of its inputs. Neural nets are sometimes constructed with sigmoid activation functions in output neurons. However, that is not needed for a neural net to be able to approximate complex functions. Moreover, sigmoid functions have restricted output range (-1 to 1 for the hyperbolic tangent function), and there will typically be dependent values outside the range. Thus using a sigmoid function in the output neuron would force an additional transformation of output values before passing training data to the net.

When MLF nets are used for classification, they have multiple output neurons, one corresponding to each possible dependent category. A net classifies a case by computing its numeric outputs; the selected category is the one corresponding to the neuron that outputs the highest value.

## MLF Net Training

Training an MLF net consists of finding a set of connection weights and bias terms that will get the net to generally give right answers when presented with new cases (for simplicity the bias term will be omitted in the presentation below). Training starts by assigning a set of randomly selected connection weights. A prediction is made for each training case (by presenting independent values as inputs to obtain the output). The output will most likely be different from the known dependent value. Thus for each training case we have an error value. From these we compute an error measure for the entire training set; it tells us how well the net does given the initial weights.

The net will probably not do very well with the random initial assignment of weights, and we proceed to subsequent trials: other assignments of weights. However, the assignments of weights are no longer random, but rather are decided by our training algorithm: the method for selecting connection weights based on results of previous trials. The problem is one of optimization: we want to minimize the error measure by changing connection weights.

### ***Historical Background***

The first successful algorithm for training connection weights in MLF nets was "back-propagation"; researchers now tend to favor other algorithms as faster and more likely to find the global optimum. NeuralTools uses the "Conjugate Gradient Descent" method, belonging to the category of "second-order" optimization methods. These "deterministic" optimization methods are designed to find the local minimum of a function: they proceed efficiently down the slope of the error function. To reduce the risk of finding the local rather than the global minimum, NeuralTools combines "deterministic" with "stochastic" optimization methods. Specifically, the stochastic "Simulated Annealing" method is used along with the Conjugate Gradient Descent method. The algorithm decides which method to use at a particular point, based on the results of previous trials. For more information on the Conjugate Gradient Descent method see Bishop (1995) and Masters (1995). For more information on Simulated Annealing see Masters (1995).

## **Error Measures**

The error measure used when training numeric prediction nets is the Mean Squared Error over all the training cases, that is the mean squared difference between the correct answer, and the answer given by the net. With classification, we have more than one output for each training case (with one output corresponding to each dependent category). We compute the Mean Squared Error over all the outputs for all the training cases, by reference to the desired output values: for each training case we want the output value to be close to 1 for the output corresponding to the correct category, and we want the remaining output values to be close to 0.

## **Training Time**

The NeuralTools MLF training algorithms restarts itself multiple times from different initial starting weights. Therefore, the longer a net is trained, the better. The more times it is allowed to restart itself, the more likely it is that the global minimum of the error function will be found.

## **Topology Selection**

The selection of the number of layers and the numbers of neurons in the layers determines whether the net is capable of learning the relationship between the independent variables and the dependent one. Typically a net with a single hidden layer and two hidden neurons will not train to a satisfactory error level. However, increasing the number of layers and neurons comes at a price that is often not worth paying. A single hidden layer is sufficient for almost any problem; using two layers will typically result in unnecessarily long training times. Moreover, a few neurons in a single hidden layer are typically sufficient.

NeuralTools can auto-configure the net topology based on training data. However, the Best Net Search feature offers a more reliable approach. As part of the Best Net Search a range of single-hidden-layer nets with different numbers of neurons will be trained. By default, five MLF nets, with 2 to 6 hidden neurons will be included. If sufficient time is available, the range can be broadened; but it is recommended that it start with a 2-neuron net, for reasons related to preventing over-training.

## **Preventing Over-Training**

The term "over-training" refers to the situation where the net learns not only the general characteristics of the relationship between independent variables and the dependent one, but instead starts learning facts about training cases that will not apply in general; that is, they will not apply to cases not included in training. Sometimes to address this problem the testing set is divided into testing-while-training set, and the proper testing set, to be used after training. The error on the testing-while-training set is periodically computed during training. When it starts to increase, this is taken as evidence that the net is beginning to over train, and training is stopped.

NeuralTools takes a different approach to preventing over-training. The approach with two distinct testing sets is often unrealistic, insofar as typically there is not enough data to split into a training set and two testing sets. Also, the increase of error on a testing-while-training set is not a reliable indicator of over-training; the increase could be local, and the error might continue to decrease with more training. NeuralTools' Best Net Search is designed to prevent over-training. With default settings, Best Net Search will start with a net with 2 neurons, which is typically too small to get over-trained. With default settings it will train nets with up to 6 neurons. If the nets with 5 and 6 neurons over-train, that will show in the results from the single testing set; one of the nets with 2, 3 or 4 neurons will have the lowest testing error.

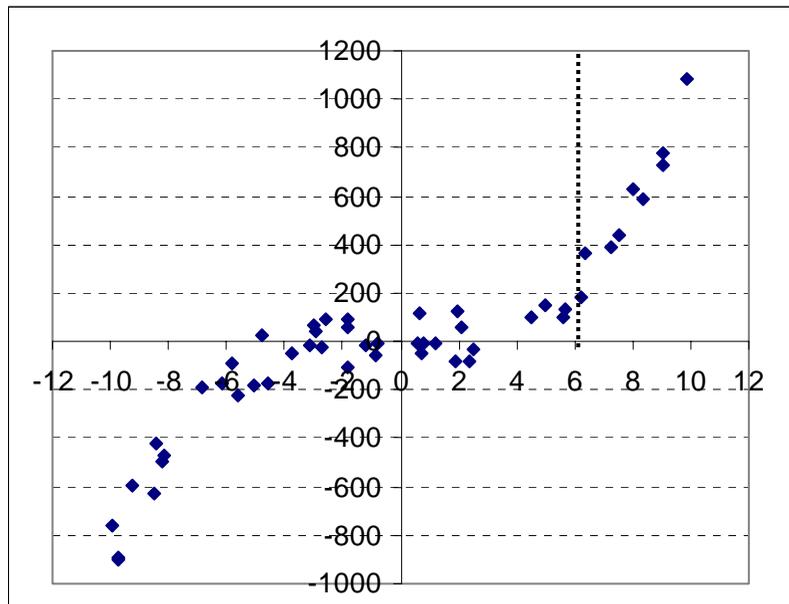


# Generalized Regression Neural Nets and Probabilistic Neural Nets

Generalized Regression Neural Nets and Probabilistic Neural Nets are based on similar ideas. GRN nets are used for numeric prediction/function approximation, while PN nets are used for category prediction/classification. Both types of nets were put forward by Donald Specht ("Probabilistic Neural Networks", *Neural Networks*, 3, 1990, pp. 109-118; "A General Regression Neural Network", *IEEE Transactions on Neural Networks*, 2, 1991, pp. 568-576). They are covered in Masters (1995), whose presentation is summarized below. Please consult these sources for additional details.

## Generalized Regression Neural Nets

By way of example, consider the training data set presented in the graph, with one independent numeric variable, and one dependent numeric variable.

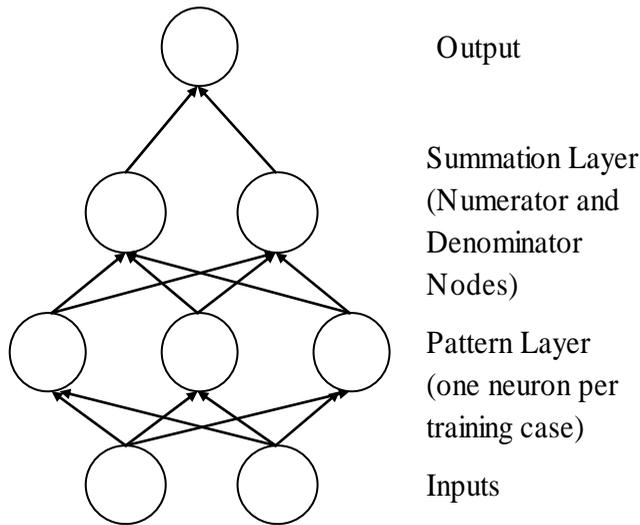


A human observer can discern a pattern in the data. If asked about the unknown dependent value for the independent value 6, we can estimate it as greater than 200 and smaller than 400. Note that this estimate is not based on the two closest known cases, which would indicate a value below 200; we look at cases beyond the closest ones.

However, we do not pay much attention to cases with independent values around -10; the closer a known case is to the unknown one, the more weight it is given when estimating the unknown dependent value. The Generalized Regression Neural Net is built on these intuitive ideas. Every training case is represented in the net. When presented with a case, the net computes the predicted dependent value using the dependent values of every training case, with closer training cases contributing more significantly to the value of the output.

**GRN  
Architecture**

A Generalized Regression Neural Net for two independent numeric variables is structured as shown in the graph (assuming there are just three training cases):



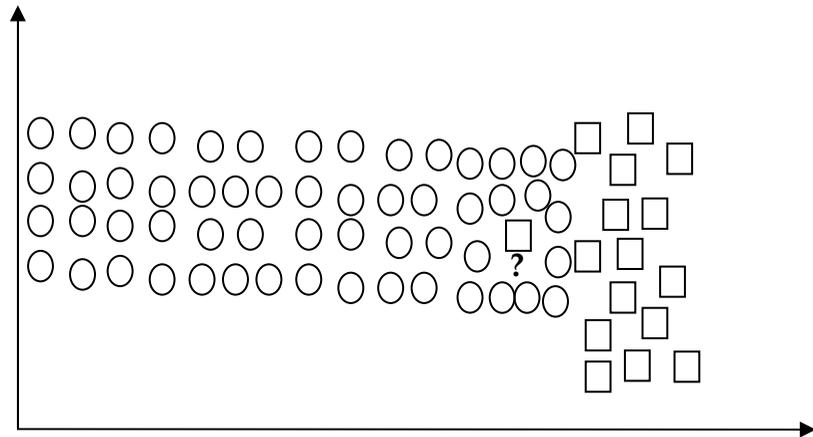
The Pattern Layer contains one node for each training case. Presenting a training case to the net consists here of presenting two independent numeric values. Each neuron in the pattern layer computes its distance from the presented case. The values passed to the Numerator and Denominator Nodes are functions of the distance and the dependent value. The two nodes in the Summation Layer sum its inputs, while the Output Node divides them to generate the prediction.

The distance function computed in the Pattern Layer neurons uses "smoothing factors"; every input has its own "smoothing factor" value. With a single input, the greater the value of the smoothing factor, the more significant distant training cases become for the predicted value. With 2 inputs, the smoothing factor relates to the distance along one axis on a plane, and in general, with multiple inputs, to one dimension in multi-dimensional space.

Training a GRN net consists of optimizing smoothing factors to minimize the error on the training set, and the Conjugate Gradient Descent optimization method is used to accomplish that. The error measure used during training to evaluate different sets of smoothing factors is the Mean Squared Error. However, when computing the Squared Error for a training case, that case is temporarily excluded from the Pattern Layer. This is because the excluded neuron would compute a zero distance, making other neurons insignificant in the computation of the prediction.

## Probabilistic Neural Nets

Turning to Probabilistic Neural Nets, consider the following training data set with 2 independent numeric variables, and a dependent variable with 2 categories:

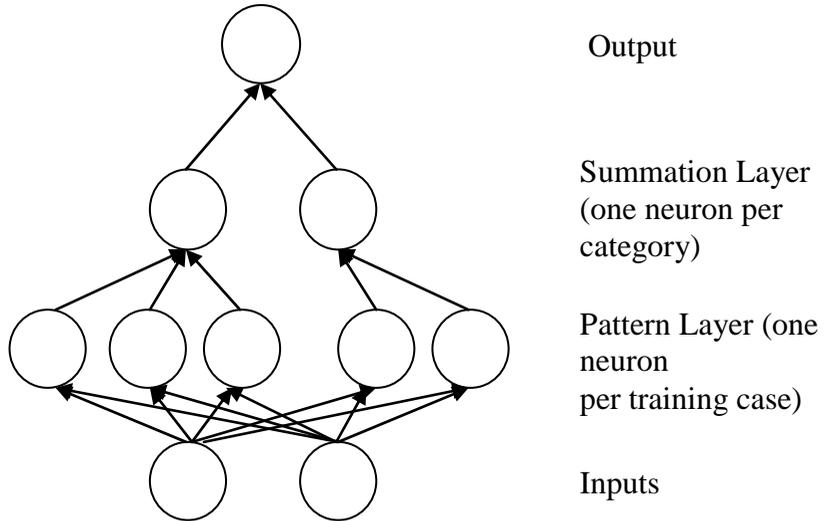


The circles represent training cases in one category, while the squares designate those belonging to the other category. We want to predict the category of the case shown as the question mark. A human observer will decide that the case is more likely in the circle category than the square category. However, many classification methods will not be able to reach the same conclusions. Methods that require linear separability of categories will fail. Nearest neighbor methods will assign the unknown case into the square category. So will methods that focus on central tendencies, since the unknown case is closer to the centroid of the square category than to the centroid of the circle category.

On the other hand, a PN net will make the correct prediction. It will consider the distance of the new case to every training case, giving greater weight to closer cases. The effect of the neighboring square will be outweighed by the circles in the immediate vicinity.

**PNN  
Architecture**

A Probabilistic Neural Net is structured as shown in the graph, which assumes there are two independent numeric variables, two dependent categories, and five training cases (three in one category and two in the other):



When a case is presented to the net, each neuron in the Pattern Layer computes the distance between the training case represented by the neuron, and the input case. The value passed to Summation Layer neurons is a function of the distance and smoothing factors. Like with GRN nets, each input has its own smoothing factor; those factors determine how rapidly the significance of training cases decreases with distance. In the Summation Layer there is one neuron per dependent category; each neuron sums up the output values for the neurons corresponding to the training cases in that category. The output values of the Summation Layer neurons can be interpreted as probability density function estimates for each class. The output neuron selects the category with the highest probability density function value as the predicted category.

Like with GRN nets, training a PN net consists of optimizing smoothing factors to minimize the error on the training set, and the Conjugate Gradient Descent optimization method is used. The error measure used during training to evaluate different sets of smoothing factors is computed based on all the values returned by neurons in the Summation Layer for all the training cases. The measure takes into account not only the probability assigned to the correct category, but also distribution of probabilities assigned to incorrect categories (approximately uniform distribution of probabilities among incorrect categories is better than some incorrect category having a large probability). Note that when computing the error for a training case, that case is temporarily excluded from the Pattern Layer. This is because the excluded neuron would compute a zero distance, making other neurons insignificant in the computation.



# Comparison of MLF Nets to PN/GRN Nets

Each of the types of Neural Networks available in NeuralTools has advantages and disadvantages, as described here:

## **Advantages of GRN/PN nets:**

- Train fast
- Do not require topology specification (numbers of hidden layers and nodes)
- PN nets not only classify, but also return the probabilities that the case falls in different possible dependent categories

## **Advantages of MLF nets:**

- Smaller in size, thus faster to make predictions
- More reliable outside the range of training data (for example, when the value of some independent variable falls outside the range of values for that variable in the training data); though note that prediction outside the range of training data is still risky with MLF nets
- Capable of generalizing from very small training sets



# Input Transformation

NeuralTools scales numeric variables before training, so that the values of each variable are approximately in the same range. This is done to equalize the effect variables have on net output during initial stages of training. When a variable is not significant for making correct predictions, this will be reflected during training by reducing the weights of connections leading from an input to first-hidden-layer neurons. However, if that insignificant variable happens to have a larger order of magnitude than other variables, the weights need to be reduced so much more to compensate for the greater values.

The scaling uses the mean and the standard deviation for each variable, computed on the training set. The mean is subtracted from each value, and the result is divided by the standard deviation. The same scaling parameters are used when testing the trained net or using it to make predictions.

Category/symbolic data cannot be used directly with a neural net, which takes numbers as inputs. Consequently, every independent category variable is represented by a number of numeric net inputs, one for every possible category. The "one-of-n" conversion method is used. For example, consider the following set of training cases:

Age	State	Loan Amount	Dependent: Loan Payment
41	NY	4000	timely
32	CT	7000	late
54	NJ	6000	timely
37	NY	5000	default

They are presented to the net as:

Age	State=CT	State=NJ	State=NY	Loan Amount	Dependent: Loan Payment
41	0	0	1	4000	timely
32	1	0	0	7000	late
54	0	1	0	6000	timely
37	0	0	1	5000	default



# Recommended Readings

The following texts provide additional background on the neural networks used in NeuralTools:

Bishop, Christopher M., *Neural Networks for Pattern Recognition*, Oxford, 1995.

Masters, Timothy, *Advanced Algorithms for Neural Networks*, Wiley, 1995.

Reed, Russell D., Robert J. Marks, *Neural Smithing*, MIT, 1999.



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# Index

## A

Application Settings Command, 69  
**Automatically Test on**, 45

## C

**Classification Matrix**, 54  
**Classification Problems**, ii  
Combining Training, Testing and Prediction, 22  
Comparison of MLF Nets to PN/GRN Nets, 93

## D

Data Set and Variable Capacities, 43  
**Data Set Manager**, 20  
Data Set Manager Command, 39  
Data Set Manager Dialog Box, 40  
Data Sets, 19  
Data Sets and Variables, 39

## E

Evolver, 30

## G

**Generalized Regression Neural Networks**, 22, 48, 87  
GRN Architecture, 88

## H

**Histogram of Residuals**, 55

## I

Icons

Desktop, 8  
NeuralTools, 35  
Icons in Dialog Boxes, 38  
Input Transformation, 95  
Installation Instructions, 7–8

## L

Live Prediction, 28, 66

## M

Missing Data Utilities Command, 74  
Missing Values, 76  
MLF Architecture, 81  
MLF Net Training, 83  
**Multi-Layer Feedforward Network**, 48, 81  
Multiple Range Data Sets, 41

## N

Neural Net Manager Command, 72  
Neural Nets vs. Statistical Methods, 77  
**Numeric Problems**, ii

## P

Palisade Corporation, 5  
PNN Architecture, 90  
Predict Command, 64  
**Prediction**, 18, 27  
Prediction Preview, 67  
Preventing Over-Training, 84  
**Probabilistic Neural Networks**, 48, 89  
Professional Version, iii

## Q

Quick Summaries in Detailed Reports, 63

## R

**Root Mean Square Error**, 55  
**Runtime**, 50

## S

Solver, 30  
StatTools, 30  
System Requirements, 6

## T

**Tag variables**, 43

Test Command, 56  
**Testing**, 18  
Testing a Network, 26  
Testing Preview, 58  
Testing Reports, 26, 59  
Toolbars  
    NeuralTools, 35  
Train Command, 44  
**Training**, 18  
Training Progress, 52  
Training Reports, 53

## U

Uninstalling NeuralTools, 7

## V

**Variable Matching**, 57  
**Variable Type**, 42