



The Dyalog Cookbook

for Windows

Stephen Taylor & Kai Jaeger

The Dyalog Cookbook

Stephen Taylor and Kai Jaeger

© 2015 - 2016 Stephen Taylor and Kai Jaeger

With grateful thanks to Kenneth E. Iverson (1920-2004), for a language we can think in, and to his collaborators and followers who make it work.

Contents

Introduction	i
Method	i
What you need to use the Dyalog Cookbook	ii
Acknowledgements	ii
1. Packaging your application	1
Structure	2
How can you distribute your program?	2
Where should you keep the code?	3
Versions	3
The MyApp workspace	4
Project Gutenberg	8
MyApp reloaded	9
Building from a DYAPP	9
Package MyApp as an executable	14
Output to the session log	14
Reading arguments from the command line	14
Logging what happens	16
Where to keep the logfiles?	17
Handling errors	20
What are we missing?	20
Inspecting Windows exit codes	20
Foreseen errors	20
Unforeseen errors	25
Crash files	29
Configuration settings	32
Using the Windows Registry	33
INI, JSON, or XML configuration files?	33
Parameters for MyApp	33

CONTENTS

Configuration <i>à la mode</i>	34
Sources of configuration parameters	34
Manifest	35
Configuration parameters in program code	36
Case and configuration parameters	37
Checking the agenda	38
Initialising the workspace	39
What we think about when we think about encapsulating state	40
Accents	41
Putting it together	43
Testing: the sound of breaking glass	46
Why you want to write tests	46
Why you don't want to write tests	48
Setting up the test environment	48
Unit and functional tests	49
Writing unit tests	50
Make me	57
Make me whole, make me lean	57
Refactoring	58
Testing the EXE	64
Workflow	66
The Doc is in	67
Testing in different versions of Windows	68
User interface – native	69
A simple UI with native Dyalog forms	69
Providing help	70
Writing an installer	71
Working with other processes	72
Launching tasks	72
Running as a Windows service	72
Sharing files	72
Communicating through TCP/IP	72
Managing your source code	73
Documentation	73
FIRE	73
CompareSimple	73

CONTENTS

Useful user commands	73
Storing data	74
Native and component files	74
XML	74
JSON	74
Relational databases	74
User interface – WPF	75
User interface – HTTP	76
Deploying as a Web application	77
Deploying as a Web service	78
 2. Professional programming practices	 79
Minimise semantic distance	80
No names	80
Delta, the Heraclitean variable	81
Stay DRY – don’t repeat yourself	82
Define variables once – if that	82
APL.local	83
Defining ubiquitous utilities	83
Some utilities you might like to make ubiquitous	83
Hooray for arrays	84
Functional is funky	85
Complex data structures	86
Passing parameters perfectly	87
The ghastliness of globals	88
Coding with class	89

Introduction

You want to write a Windows¹ application in Dyalog APL. You have already learned enough of the language to put some of your specialist knowledge into functions you can use in your work. The code works for you. Now you want to turn it into an application others can use. Perhaps even sell it.

This is where you need professional programming skills. How to install your code into an unknown computer. Have it catch, handle and log errors. Manage the different versions of your software as it evolves. Provide online help.

You are not necessarily a professional programmer. Perhaps you don't have those skills. Perhaps you need a professional programmer to turn your code into an application. But you've come a long way already. Perhaps you can get there by yourself - with *The Dyalog Cookbook*. Alternatively, you might be a professional programmer wondering how to solve these familiar problems in Dyalog APL.

The Dyalog Cookbook is about how to turn your Dyalog code into an application. We'll cover packaging your code into a robust environment. And we'll introduce some software development tools you've managed without so far, which will make your life easier.

You might continue as the sole developer of your application for a long time yet. But if it becomes a successful product you will eventually want other programmers collaborating on it. So we'll set up your code in a source-control system that will accommodate that. Even while you remain a sole developer, a source-control system will also allow you to roll back and recover from your own mistakes.

Not so long ago it was sufficient for an application to be packaged as an EXE that could be installed and run on other PCs. Nowadays many corporate clients run programs in terminal servers or in private clouds. So we'll look at how to organise your program to run as tasks that communicate with each other. Many applications written in Dyalog focus on some kind of numerical analysis, and can have CPU-intensive tasks. We'll look at how such tasks can be packaged to run either in background or on remote machines.

Method

It's conventional in this context for authors to assure readers that the techniques expounded here have been hammered out, proven and tested in many successful applications. That is true of individual components here, particularly of scripts from the APLTree library. But the development tools introduced by Dyalog in recent years are still finding their places with development teams.

¹Perhaps one day you would like it to ship on multiple platforms. Perhaps one day we'll write that book too. Meanwhile, Microsoft Windows.

Some appear here in print for the first time. This book is the first sustained attempt to combine all the current Dyalog tools into an integrated approach.

Many of the issues addressed here are entangled with each other. We'll arrive at our best solutions by way of interim solutions. Proposing some wickedly intricate 'complete solution' framework does little to illuminate the problems it solves. So we'll add features – INI files, error handling, and so on – one at a time, and as we go we'll find ourselves revisiting the code that embeds the earlier features.

If you are an experienced Dyalog developer, you may be able to improve on what is described here. For this reason *The Dyalog Cookbook* remains for now [an open-source project on GitHub](https://github.com/5jt/dyalog-cookbook)².

Working through book, you get to understand how the implementation issues and the solutions to them work. In Part 1 you will find 'framework' code for your application, growing more complex as the book progresses. You can find scripts for these interim versions in the `code` folder on the book website. Watch out: they are interim solutions. You are of course welcome to simply copy and use the last version of the scripts. But there is much to be learned while stumbling.

Finally in Part 2 we'll introduce some professional writing techniques that might make maintaining your code easier – in what we hope will be a long useful future for it!

What you need to use the Dyalog Cookbook

- The Dyalog Version 15.0 Unicode interpreter or later.
- To know how to use namespaces, classes and instances. The utility code in the Cookbook is packaged as namespaces and classes. This is the form in which it is easiest for you to slide the code into your app without name conflicts. We recommend you use classes to organise your own code! But even if you don't, you need to know at least how to use classes. This is a deep subject, but all you need to know is the basics: creating an instance of a class and using its methods and properties, or just using the methods of a static class. See *Dyalog Programmer's Reference Guide* for an introduction.

We have not attempted to 'dumb down' our use of the language for readers with less experience. In some cases we stop to discuss linguistic features; mostly not. If you see an expression you cannot read, a little experimentation and consultation of the reference material should show how it works. We encourage you to take the time to do this. Generally speaking – not invariably – short, crisp expressions are less work for you and the interpreter to read. Learn them and prefer them.

Acknowledgements

We are deeply grateful for contributions, ideas, comments and outright help from our colleagues, particularly from Gil Athoraya, Morten Kromberg, Nick Nickolov, and Paul Mansour.

²<https://github.com/5jt/dyalog-cookbook>

We jealously claim any errors as entirely our own work.

Stephen Taylor & Kai Jaeger

1. Packaging your application

Structure

In this chapter we consider your choices for making your program available to others, and for taking care of the source code, including tracking the changes through successive versions.

To follow this, we'll make a very simple program. It counts the frequency of letters used in one or multiple text files. (This is simple, but useful in cryptanalysis, at least at hobby level.) We'll put the source code under version control, and package the program for use.

Let's assume you've done the convenient thing. Your code is in a workspace. Everything it needs to run is defined in the workspace. Maybe you set a latent expression, so the program starts when you load the workspace.

In this chapter, we shall convert a DWS (saved workspace) to some DYALOG scripts and a DYAPP script to assemble an active workspace from them.

How can you distribute your program?

Send a workspace file (DWS)

Could not be simpler. If your user has a Dyalog interpreter, she can also save and send you the crash workspace if your program hits an execution error. But she will also be able to read your code – which might be more than you wish for.

If she doesn't have an interpreter, and you are not worried about her someday getting one and reading your code, and you have a Run-Time Agreement with Dyalog, you can send her the Dyalog Run-Time interpreter^[^ext] with the workspace. The Run-Time interpreter will not allow the program to suspend, so when the program breaks the task will vanish, and your user won't see your code. All right so far. But she will also not have a crash workspace to send you.

If your application uses multiple threads, the thread states can't be saved in a crash workspace anyway.

You need your program to catch and report any errors before it dies.

Send an executable file (EXE)

This is the simplest form of the program to install, because there is nothing else it needs to run: everything is embedded within the EXE. You export the workspace as an EXE, which can have the Dyalog Run-Time interpreter bound into it. The code cannot be read. As with the workspace-based runtime above, your program cannot suspend, so you need it to catch and report any errors before dying.

We'll do that!

Where should you keep the code?

Let's start by considering the workspace you will export as an EXE.

The first point is PCs have a lot of memory relative to your application code volume. So all your Dyalog code will be in the workspace. That's probably where you have it right now: all saved in a workspace.

Your workspace is like your desk top – a great place to get work done, but a poor place to store things. In particular it does nothing to help you track changes and revert to an earlier version.

Sometimes a code change turns out to be for the worse, and you need to undo it. Perhaps the change you need to undo is not the most recent change.

We'll keep the program in manageable pieces – 'modules' – and keep those pieces in text files under version control.

For this there are many *source-control management* (SCM) systems and repositories available. Subversion, GitHub and Mercurial are presently popular. These SCMs support multiple programmers working on the same program, and have sophisticated features to help resolve conflicts between them.

Whichever SCM you use (we used GitHub for writing this book and the code in it) your source code will comprise class and namespace scripts (DYALOGs) and a *build script* (DYAPP) to assemble them.

You'll keep your local working copy in whatever folder you please. We'll refer to this *working folder* as `Z:\` but it will of course be wherever suits you.

Versions

In real life you will produce successive *versions* of your program, each better than the last. In an ideal world, all your users will have and use the latest version. In that ideal world, you have only one version to maintain: the latest. In the real world, your users will have and use multiple versions. If you charge for upgrading to a newer version, this will surely happen. And even in your ideal world, you have to maintain at least two versions: the latest and the next.

What does it mean to maintain a version? At the very minimum, you keep the source code for it, so you could recreate its EXE from scratch, exactly as it was distributed. There will be things you want to improve, and perhaps bugs you must fix. Those will all go into the next version, of course. But some you may need to put into the released version and re-issue it to current users as a patch.

So in *The Dyalog Cookbook* we shall develop in successive versions. Our 'versions' are not ready to ship, so are probably better considered as milestones on the way to version 1.0. You could think of them as versions 0.1, 0.2 and so on. But we'll just refer to them as Versions 1, 2, and so on.

Our first version won't even be ready to export as an EXE. It will just recreate MyApp.DWS from scripts: a DYAPP and some DYALOGs. We'll call it Version 0.

The MyApp workspace

We suppose you already have a workspace in which your program runs. We mean to get from your workspace to class and namespace scripts and a build script.

We don't have your wonderful code to hand so we'll use ours. We'll use a very small and simple program, so we can focus on packaging the code as an application, not on writing the application itself.

Your application will of course be much more interesting!

So we'll begin with the MyApp workspace. It's trivially simple (we'll extend a bit what it does as we go) but for now it will stand in for your much more interesting code.

On encryption

Frequency counting relies on the distribution of letters being more or less constant for any given language. It is the first step in breaking a substitution cypher. Substitution cyphers have been superseded by public-private key encryption, and are mainly of historical interest, or for studying cryptanalysis. But they are also fun to play with.

We recommend *The Code Book: The secret history of codes & code-breaking* by Simon Singh and *In Code* by Sarah Flannery as introductions if you find this subject interesting.

From the `code\v01` folder on the book website load `LetterCount.dws`. Again, this is just the stand-in for your own code. Here's a quick tour.

Discussion

Function `TxtToCsv` takes the filepath of a TXT (text file) and writes a sibling CSV file containing the frequency count for the letters in the file. It uses function `CountLetters` to produce the table.

```

Δ←'Now is the time for all good men'
Δ,←' to come to the aid of the party.'
MyApp.CountLetters Δ

N 2
O 8
W 1
I 3
S 1
T 7
H 3
E 6

```

```

M 3
F 2
R 2
A 3
L 2
G 1
D 2
C 1
P 1
Y 1

```

`CountLetters` returns a table of the letters in `⍳A` and the number of times each is found in the text. The count is insensitive to case and ignores accents, mapping accented to unaccented characters:

```

ACCENTS
ÁÂÃÄÅÄÇÐÈÉÊËÌÍÎÏÑÒÓÔÕÖØÙÚÛÜÝ
AAAAAACDEEEEEIIIIINOOOOOOUUUUUY

```

That amounts to five functions. Two of them are specific to the application: `TxtToCsv` and `CountLetters`. The other three – `caseUp`, `join`, and `map` are utilities, of general use.

`toUppercase` uses the fast case-folding I-beam introduced in Dyalog 15.0.

`TxtToCsv` uses the file-system primitives `⍋NINFO`, `⍋NGET`, and `⍋NPUT` introduced in Dyalog 15.0.

`TxtToCsv` observes *Cannon's Canon*, which tells us to avoid representing options with numeric constants. Instead, it assigns descriptive names at the start and uses those. That's not too bad, but if every function did the same, we risk multiple definitions of the same constant, breaching the DRY principle – don't repeat yourself. (And open to errors: *A man with two watches never knows what time it is.*) We can do better by defining all the Dyalog constants we want to use in a single namespace in the root.

How to organise the code

To expand this program into distributable software we're going to add features, many of them drawn from the [APLTree library](http://archive.vector.org.uk/art10500730)³. To facilitate that we'll first organise the existing code into script files, and write a *build script* to assemble a workspace from them.

Start at the root. We're going to be conservative about defining names in the root of the workspace. Why? Right now the program stands by itself and can do what it likes in the workspace. But in the future your program might become part of a larger APL system. In that case it will share the workspace root with other objects you don't know anything about right now.

³<http://archive.vector.org.uk/art10500730>

So your program will be a self-contained object in the workspace root. Give it a distinctive name, not a generic name such as `Application` or `Root`. From here on we'll call it `MyApp`. (We know: almost as bad.)

But there *are* other objects you might define in the root. If you're using classes or namespaces that other systems might also use, define them in the root. For example, if `MyApp` should one day become a module of some larger system, it would make no sense for each module to have its own copy of, say, the `APLTree` class `Logger`.

With this in mind, let's distinguish some categories of code, and how the code in `MyApp` will refer to them.

General utilities and classes

For example, the `APLTreeUtils` namespace and the `Logger` class. (Your program doesn't yet use these utilities.) In the future, other programs, possibly sharing the same workspace, might use them too.

Your program and its modules

Your top-level code will be in `#.MyApp`. Other modules and `MyApp`-specific classes may be defined within it.

Tools and utility functions specific to MyApp

These might include your own extensions to Dyalog namespaces or classes. Define them inside the app object, eg `#.MyApp.Utils`.

Your own language extensions and syntax sweeteners

For example, you might like to use functions `means` and `else` as simple conditionals. These are effectively your local *extensions* to APL, the functions you expect always to be around. Define your collection of such functions into a namespace in the root, eg `#.Utilities`.

The object tree in the workspace might eventually look something like:

```
#
|-⊙Constants
|-⊙APLTreeUtils
|-⊙Utilities
|-⊙MyApp
|  |-⊙Common
|  |-⊙Engine
|  |-⊙TaskQueue
|  \-⊙UI
|  \-⊙Utils
\--⊙Logger
```



⊛ denotes a namespace, ○ a class.

The objects in the root are ‘public’. They comprise `MyApp` and objects other applications might use. (You might add another application that uses `#.Utilities`. Everything else is encapsulated within `MyApp`. Here’s how to refer in the `MyApp` code to these different categories of objects.

```
1. log←NEW #.Logger
2. queue←NEW TaskQueue
3. tbl←Engine.CountLetters txt
4. foo←(bar>3) #.Utilities.means 'ok' #.Utilities.else 'error'
```

That last is pretty horrible. It needs some explanation.

Many languages offer a short-form syntax for if/else, eg (JavaScript, PHP)

```
foo = bar>3 ? 'ok' : 'error' ;
```

Some equivalents in Dyalog:

```
:If bar>3 ◇ foo←'ok' ◇ :Else ◇ foo←'error' ◇ :EndIf
foo←(IO+bar>3)◇'error' 'ok'
foo←(bar>3)φ'error' 'ok'
```

`means` and `else` here provide a short-form syntax:

```
foo←(bar>3) means 'ok' else 'error'
```

The readability gain is largely lost if we have to qualify the functions with their full paths:

```
foo←(bar>3) #.Utilities.means 'ok' #.Utilities.else 'error'
```

We can improve it by defining aliases within `#.MyApp`:

```
(C U)←#.(Constants Utilities)
```

allowing (4) to be written as


```
foo←(bar>3) U.means 'ok' U.else 'error'
```

Why not use □PATH?

□PATH tempts us. We could set □PATH←'#.Utilities'. The expression above could then take its most readable form:

```
foo←(bar>3) means 'ok' else 'error'
```

Trying to resolve the names `means` and `else`, the interpreter would consult □PATH and find them in `#.Utilities`. So far so good: this is what □PATH is designed for. It works fine in simple cases, but it will lead us into problems later:

- As long as each name leads unambiguously to an object, shift-clicking on it will display it in the editor, a valuable feature of APL in development and debugging. The editor allows us to change code during execution, and save those changes back to the scripts. But □PATH can interfere with this and break that valuable connection.
- Understanding the scope of the space in which a GUI callback executes can be challenging enough; introducing □PATH makes it harder still.

Project Gutenberg

We'll raid [Project Gutenberg](https://www.gutenberg.org/)⁴ for some texts to read.

We're tempted by the complete works of William Shakespeare but we don't know that letter distribution stayed constant over four centuries. Interesting to find out, though, so we'll save a copy as `Z:\texts\en\shakespeare.dat`. And we'll download some 20th-century books as TXTs into the same folder. Here are some texts we can use.

```
↑>(□NINFO□'Wildcard' 1) 'z:\texts\en\*.txt'
z:/texts/en/ageofinnocence.txt
z:/texts/en/dubliners.txt
z:/texts/en/heartofdarkness.txt
z:/texts/en/metamorphosis.txt
z:/texts/en/pygmalion.txt
z:/texts/en/timemachine.txt
z:/texts/en/ulysses.txt
z:/texts/en/withthesehands.txt
z:/texts/en/wizardoz.txt
```

⁴<https://www.gutenberg.org/>

MyApp reloaded

We'll first make MyApp a simple 'engine' that does not interact with the user. Many applications have functions like this at their core. Let's enable the user to call this engine from the command line with appropriate parameters. By the time we give it a user interface, it will already have important capabilities, such as logging errors and recovering from crashes.

Our engine will be based on the `TxtToCsv` function. It will take one parameter, a fully-qualified filepath for a folder or file. If a file, it will write a sibling CSV. If a folder, it will read any TXT files in the folder, count the letter frequencies and report them as a CSV file sibling to the folder. Simple enough. Here we go.

Building from a DYAPP

In your text editor open a new document. (Or you can take the DYAPP from the folder for this chapter.)



You need a text editor that handles Unicode. If you're not already using a Unicode text editor, Windows' own Notepad will do for occasional use. (Set the default font to APL385 Unicode.) For a full-strength multifile text editor [Notepad++⁵](https://notepad-plus-plus.org/) works well.

Here's how the object tree will look:

```
#  
|-*Constants  
|-*Utilities  
\\-*MyApp
```



See the *SALT User Guide* for more about DYAPPs.

The file tree will look like this:

⁵<https://notepad-plus-plus.org/>

```
z:\code\v01\Constants.dyalog
z:\code\v01\MyApp.dyalog
z:\code\v01\Utilities.dyalog
z:\code\v01\MyApp.dyapp
```

So `z:\code\v01\MyApp.dyapp` looks like this:

```
Target #
Load Constants
Load Utilities
Load MyApp
```

and the DYALOGs look like this. `Constants.dyalog`:



You can download all the scripts in this chapter from the corresponding folder in the book website. Or create the namespaces in the session and use SALT to save them to files.

```
:Namespace Constants
  A Dyalog constants

  :Namespace NINFO

    A left arguments
    NAME←0
    TYPE←1
    SIZE←2
    MODIFIED←3
    OWNER_USER_ID←4
    OWNER_NAME←5
    HIDDEN←6
    TARGET←7
```

```

:Namespace TYPES
  NOT_KNOWN←0
  DIRECTORY←1
  FILE←2
  CHARACTER_DEVICE←3
  SYMBOLIC_LINK←4
  BLOCK_DEVICE←5
  FIFO←6
  SOCKET←7
:EndNamespace

:EndNamespace

:Namespace NPUT
  OVERWRITE←1
:EndNamespace

:EndNamespace

```

Later on we'll introduce a more convenient way to represent and maintain the definitions of constants. This will do nicely for now.

And Utilities.dyalog:

```

:Namespace Utilities

  map←{
    (old new)←α
    nw←αω
    (new,nw)[(old,nw)ιω]
  }

  toLowercase←0◊(819I)
  toUppercase←1◊(819I)

:EndNamespace

```

And another:

```

:Namespace MyApp

# Aliases
(C U)←#.(Constants Utilities) # must be already defined

# === VARIABLES ===

ACCENTS←↑'ÁÂÃÄÅÇÈÉÊËÌÍÎÏÑÒÓÔÕÖØÙÚÛÜÝ' 'AAAAAACDEEEIIIIINOOOOOUUUUY'

# === End of variables definition ===

CountLetters←{
  {α(≠ω)}⊞A{ω↦~ω∈α}(↓ACCENTS)U.map U.toUppercase ω
} # Table of letter counts in string ω

▽ {ok}←TxtToCsv fullfilepath;xxx;csv;stem;path;files;txt;type;lines;nl
  ;enc;tgt;src;tbl
# Write a sibling CSV of the TXT located at fullfilepath,
# containing a frequency count of the letters in the file text
  csv←'.csv'
  :Select type←C.NINFO.TYPE ⊞NINFO fullfilepath
  :Case 1 # folder
    tgt←fullfilepath,csv
    files←(⊞NINFO⊞'Wildcard' 1)fullfilepath,'*.txt'
  :Case 2 # file
    (path stem xxx)←⊞NPARTS fullfilepath
    tgt←path,stem,csv
    files←,cfullfilepath
  :EndSelect
  tbl←0 2p'A' 0
  :For src :In files
    (txt enc nl)←⊞NGET src
    tbl;←CountLetters txt
  :EndFor
  lines←{α,',',,⊞ω}/>{α(+/ω)}⊞/[1]tbl
  ok←x(lines enc nl)⊞NPUT tgt C.NPUT.OVERWRITE
▽

#EndNamespace

```

Launch the DYAPP by double-clicking on its icon in Windows Explorer. Examine the active session. We see

- Constants
 - NINFO
 - NAME
 - ...
 - TYPES
 - NOT_KNOWN
 - DIRECTORY
 - ...
 - NPUT
 - OVERWRITE
- MyApp
 - ACCENTS
 - CountLetters
 - TxtToCsv
- Utilities
 - map
 - toLowercase
 - toUppercase



If you also see namespaces `SALT_Data` ignore them. They are part of how the Dyalog editor updates script files.

We have converted the saved workspace to a DYAPP that assembles the workspace from DYALOGs. We can use `MyApp.dyapp` anytime to recreate the app as a workspace. But we have not saved a workspace. We will always assemble a workspace from scripts.

Package MyApp as an executable

For Version 1.0 we'll package `MyApp` as an EXE. Version 1.0 will run from the command line and it will run 'headless' – without a user interface (UI). It won't have a session either.

Output to the session log

What happens to values that would otherwise be written in the session log? They disappear. That's not actually a problem, but it is tidy to catch anything that would otherwise be written to the UI, including empty arrays.

`TxtToCsv` has a shy result, so it won't write its result to the session. That's fine.

We'll also fix three key environment variables for it in `MyApp`:

```
([IO [ML [WX])+1 1 3 A environment variables
```

Reading arguments from the command line

`TxtToCsv` needs an argument. The EXE must take it from the command line. We'll give `MyApp` a niladic function `StartFromCmdLine`. The DYAPP will use it to start the program:

```
Target #  
Load Constants  
Load Utilities  
Load MyApp  
Run MyApp.SetLX
```

and in `MyApp.dyalog`:

```

▽ SetLX
A Set Latent Expression in root ready to export workspace as EXE
#.LX←'MyApp.StartFromCmdLine'
▽

▽ StartFromCmdLine;args
A Read command parameters, run the application
  {}TtxtToCsv 2>2↑2 NQ'.' 'GetCommandLineArgs'
▽

```

This is how MyApp will run when called from the Windows command line.

We're now nearly ready to export the first version of our EXE.

1. From the File menu pick *Export*.
2. Pick Z:\ as the destination folder.
3. From the list *Save as type* pick *Standalone Executable*.
4. Set the *File name* as **MyApp**.
5. Check the *Runtime application* and *Console application* boxes.
6. Click *Save*.

You should see an alert message: *File Z:\MyApp.exe successfully created*. (This occasionally fails for no obvious reason. If it does, delete or rename any prior version and try again.)



Use the *Version* button to bind to the EXE information about the application, author, version, copyright and so on. Specify an icon file to replace the Dyalog icon with one of your own.

Let's run it. From a command line:

```

c:\Users\A.N. Other>CD Z:\
Z:\>MyApp.exe texts\en

```

Looking in Windows Explorer at Z:\texts\en.csv, we see its timestamp just changed. Our EXE works!

Logging what happens

MyApp 1.0 is now working, but handles errors poorly. See what happens when we try to work on a non-existent folder. In the command shell

```
Z:\code\v01>MyApp.exe Z:\texts\de
```

We see an alert message: *This Dyalog APL runtime application has attempted to use the APL session and will therefore be closed.*

MyApp failed, because there is no folder `Z:\texts\de`. That triggered an error in the APL code. The interpreter tried to signal the error to the session. But a runtime task has no session, so at that point the interpreter popped the alert message and MyApp died.

MyApp 2.0 could do better. In several ways.

- Have the program write a log file recording what happens.
- Set traps to catch and log foreseeable problems.
- Set a top-level trap to catch and report unforeseen errors and save a crash workspace for analysis.

Save a copy of `Z:\code\v01` as `Z:\code\v02`.

Start with the log file. We'll use the `APLTree Logger` class, which we'll now install in the workspace root. If you've not already done so, copy the `APLTree` library folder into `Z:\code`.⁶ Now edit `Z:\code\v02\MyApp.dyapp` to include some library code:

```
Target #
Load ..\AplTree\APLTreeUtils
Load ..\AplTree\FilesAndDirs
Load ..\AplTree\Logger
Load Constants
Load Utilities
Load MyApp
Run MyApp.SetLX
```

and run the DYAPP to recreate the MyApp workspace.

The `Logger` class is now part of MyApp. Let's get the program to log what it's doing.

Within `MyApp`, some changes. Some aliases for the new code.

⁶You can download the complete `APLTree` library from the [APL Wiki](#).

```

A Aliases (referents must be defined previously)
  (A F L)←#.(APLTreeUtils FilesAndDirs Logger) A from APLTree
  (C U)←#.(Constants Utilities)

```

Where to keep the logfiles?

Where is MyApp to write the logfile? We need a filepath we know exists. That rules out `full-filepath`. We need a logfile even if that isn't a valid path.

We'll write logfiles into a subfolder of the Current Directory. Where will that be?

When the EXE launches, the Current Directory is set by the command shell. Eg:

```
Z:\code\v02>MyApp.exe Z:\texts\en
```

Current Directory is `Z:\code\v02` and the logfiles will appear in `Z:\code\v02\Logs`.

```
Z:>code\v02\MyApp.exe texts\en
```

Current Directory is `Z:` and the logfiles will appear in `Z:\Logs`.

If this version of MyApp were for shipping that would be a problem. An application installed in `C:\Program Files` cannot rely on being able to write logfiles there. That is a problem to be solved by an installer. We'll come to that later. But for this version of MyApp the logfiles are for your eyes only. It's fine that the logfiles appear wherever you launch the EXE. You just have know where they are.

In developing and testing MyApp, we create the active workspace by running `MyApp.dyapp`. The interpreter sets the Current Directory of the active workspace as the DYAPP's parent folder. That too is sure to exist.

```

# .FilesAndDirs.PWD
Z:\code\v02

```

We need `TxtToCsv` to ensure the Current Directory contains a `Logs` folder.

```
'CREATE!' F.CheckPath 'Logs' A ensure subfolder of current dir
```

Now we set up the parameters for the Logger object. First we use the Logger class' static `CreatePropertySpace` method to get a property space (object) with an initial a set of default parameters. We then modify those and use the object to create the Logger object. You can use the property space's `List` method to display its properties.)

If `TxtToCsv` can log what it's doing, it makes sense to check its argument. We wrap the earlier version of the function in an if/else:

```

▽ {ok}←TxtToCsv fullfilepath;Δ;csv;stem;path;files;txt;type;lines;nl
    ;enc;tgt;src;tbl
A Write a sibling CSV of the TXT located at fullfilepath,
A containing a frequency count of the letters in the file text
  'CREATE!'F.CheckPath'Logs' A ensure subfolder of current dir
  Δ←L.CreatePropertySpace
  Δ.path←'Logs\' A subfolder of current directory
  Δ.encoding←'UTF8'
  Δ.filenamePrefix←'MyApp'
  Δ.refToUtils←#
  Log←NEW L(,Δ)
  Log.Log'Started MyApp in ',F.PWD
  Log.Log'Source: ',fullfilepath

  :If ~NEXISTS fullfilepath
    Log.Log'Invalid source'
    ok←0
  :Else

    A as before...

  :EndIf
▽

```

Notice how defining the aliases A, L, and W in the namespace script – the environment of `StartFromCmdLine` and `TxtToCsv` – makes the function code more legible.

The foreseeable error that aborted the runtime task – on an invalid filepath – has now been replaced by log messages to say no files were found.

As the logging starts and ends in `TxtToCsv`, we can run this in the workspace now to test it.

```

#.MyApp.TxtToCsv 'Z:\texts\en'
=>(NINFO1) 'Logs\*.LOG'
MyApp_20160406.log
↑NGET 'Logs\MyApp_20160406.log'
2016-04-06 13:42:43 *** Log File opened
2016-04-06 13:42:43 (0) Started MyApp in Z:\code\v02
2016-04-06 13:42:43 (0) Source: Z:\texts\en
2016-04-06 13:42:43 (0) Target: Z:\texts\en.csv
2016-04-06 13:42:43 (0) 244 bytes written to Z:\texts\en.csv
2016-04-06 13:42:43 (0) All done

```

Let's see if this works also for the exported EXE. Run the DYAPP to rebuild the workspace. Export as before, but to `Z:\code\v02`, and in the Windows command line run the new `MyApp.exe`.

```
Z:\code\v02>MyApp.exe Z:\texts\en
```

Yes! The output TXT gets produced as before, and the work gets logged in Z:\code\v02\Logs.

Let's see what happens now when the filepath is invalid.

```
Z:\code\v02>MyApp.exe Z:\texts\de
```

No warning message – the program made an orderly finish. And the log?

```
↑[NGET 'Logs\MyApp_20160406.log'
2016-04-06 13:42:43 *** Log File opened
2016-04-06 13:42:43 (0) Started MyApp in Z:\code\v02
2016-04-06 13:42:43 (0) Source: Z:\texts\en
2016-04-06 13:42:43 (0) Target: Z:\texts\en.csv
2016-04-06 13:42:43 (0) 244 bytes written to Z:\texts\en.csv
2016-04-06 13:42:43 (0) All done
2016-04-06 13:42:50 *** Log File opened
2016-04-06 13:42:50 (0) Started MyApp in Z:\code\v02
2016-04-06 13:42:50 (0) Source: Z:\texts\de
2016-04-06 13:42:50 (0) Invalid source
```

Yes!

We now have MyApp logging its work in a subfolder of the application folder and reporting problems which it has anticipated.

Next we need to consider how to handle and report errors we have *not* anticipated. We should also return some kind of error code to Windows. If MyApp encounters an error, any process calling it needs to know.

Handling errors

MyApp now anticipates, tests for and reports certain foreseeable problems with the parameters. We'll now move on to handle errors more comprehensively.

Save a copy of `Z:\code\v02` as `Z:\code\v03`.

What are we missing?

1. Other problems are foreseeable. The file system is a rich source of ephemeral problems and displays. Many of these are caught and handled by the APLTree utilities. They might make several attempts to read or write a file before giving up and signalling an error. Hooray. We need to handle the events signalled when the utilities give up.
2. The MyApp EXE terminates with an all-OK zero exit code even when it has caught and handled an error. It would be a better Windows citizen if it returned custom exit codes, letting a calling program know how it terminated..
3. By definition, unforeseen problems haven't been foreseen. But we foresee there will be some! A mere typo in the code could break execution. We need a master trap to catch any events that would break execution, save them for analysis, and report them in an orderly way.

Inspecting Windows exit codes

How do you see the exit code returned to Windows? You can see it in the command shell like this:

```
Z:\code\v03>MyApp.exe Z:\texts\en
```

```
Z:\code\v03>echo Exit Code is %errorcode%  
Exit Code is 0
```

```
Z:\code\v03>MyApp.exe Z:\texts\de
```

```
Z:\code\v03>echo Exit Code is %errorcode%  
Exit Code is 101
```

Foreseen errors

We'll start with the second item from the list above. Now the result of `TxtToCsv` gets passed to `!OFF` to be returned to the operating system as an exit code.

```

▽ StartFromCmdLine;exit;args
  A Read command parameters, run the application
  □WSID←'MyApp'
  args←[]2 □NQ'.' 'GetCommandLineArgs'
  Off TxtToCsv 2>2↑args
▽

▽ Off returncode
  :If #.A.IsDevelopment
    →
  :Else
    □OFF returncode
  :Endif
▽

```

And we'll define in `#.MyApp` a child namespace of exit codes.

```

:Namespace EXIT
  OK←0
  INVALID_SOURCE←101
  UNABLE_TO_READ_SOURCE←102
  UNABLE_TO_WRITE_TARGET←103
:EndNamespace

```

We define an OK value of zero for completeness. (We really *are* trying to eliminate from our functions numerical constants that the reader has to interpret.) In Windows, an exit code of zero is a normal exit. All the exit codes are defined in this namespace. The function code can refer to them by name, so the meaning is clear. And this is the *only* definition of the exit-code values.

We could have defined EXIT in `#.Constants`, but we reserve that script for Dyalog constants, keeping it as a component that could be used in other Dyalog applications. *These* exit codes are specific to MyApp, so are better defined in `#.MyApp`.

`TxtToCsv` still starts and stops the logging, but it now calls `CheckAgenda` to examine what's to be done, and `CountLettersIn` to do them. Both these functions use the function `Error`, local to `TxtToCsv`, to log errors.

```

▽ exit←TxtToCsv fullfilepath;Δ;isDev;Log;LogError;files;tgt
  A Write a sibling CSV of the TXT located at fullfilepath,
  A containing a frequency count of the letters in the file text
  'CREATE!'F.CheckPath'Logs' A ensure subfolder of current dir
  Δ←L.CreatePropertySpace
  Δ.path←'Logs',F.CurrentSep A subfolder of current directory
  Δ.encoding←'UTF8'
  Δ.filenamePrefix←'MyApp'
  Δ.refToUtils←#
  Log←NEW L(,Δ)
  Log.Log'Started MyApp in ',F.PWD
  Log.Log'Source: ',fullfilepath

  LogError←Log°{code←EXITω ◇ code←α.LogError code ω}

  :If EXIT.OK⇒(exit files)←CheckAgenda fullfilepath
    Log.Log'Target: ',tgt←(=,/2↑NPARTS fullfilepath),'.CSV'
    exit←CountLettersIn files tgt
  :EndIf
  Log.Log'All done'
▽

```

Note the exit code is tested against `EXIT.OK`. Testing `0=exit` would work and read as well, but relies on `EXIT.OK` being 0. The point of defining the codes in `EXIT` is to make the functions relate to the exit codes only by their names.

See *Delta, the Heracitian variable* in Part 2 for a discussion of how and why we use the `Δ` variable.

`CheckAgenda` looks for foreseeable errors. In general, we like functions to *start at the top and exit at the bottom*. Returning from the middle of a function can lead to confusion. We'll come back to this topic in a moment. `CheckAgenda` follows a common pattern of validation logic: a cascade of tests with corresponding actions to handle the error, terminating in an 'all clear'.

```

▽ (exit files)←CheckAgenda fullfilepath;type
  :If ~(type←C.NINFO.TYPE □NINFO fullfilepath)∈C.NINFO.TYPES.(DIRECTORY FILE)
    (files exit)←(LogError 'INVALID_SOURCE')('')
  :ElseIf ~□NEXISTS fullfilepath
    (files exit)←(LogError 'SOURCE_NOT_FOUND')('')
  :Else
    :Select type
    :Case C.NINFO.TYPES.DIRECTORY
      files←(□NINFO□'Wildcard' 1)fullfilepath,'\*.txt'
    :Case C.NINFO.TYPES.FILE
      files←,cfullfilepath
    :EndSelect
    exit←EXIT.OK
  :EndIf
▽

```

CountLettersIn can get to work now knowing its arguments are valid. But it's working with the file system, and valid file operations can fail for all sorts of reasons, including unpredictable and ephemeral network conditions. So we set traps to catch and report failures.

```

▽ exit←CountLettersIn (files tgt);i;txt;tbl;enc;nl;lines;bytes
  A Exit code from writing a letter-frequency count for a list of files
  tbl←0 2p'A' 0
  exit←EXIT.OK ♦ i←1
  :While exit=EXIT.OK
    :Trap 0
      (txt enc nl)←□NGET i>files
      tbl←CountLetters txt
    :Else
      exit←LogError 'UNABLE_TO_READ_SOURCE'
    :EndTrap
  :Until (≠files)<i←i+1
  :If exit=EXIT.OK
    lines←{α,',',⌘}/>{α(+/ω)}⌘/↓[1]tbl
    :Trap 0
      bytes←(lines ec nl)□NPUT tgt C.NPUT.OVERWRITE
    :Else
      exit←LogError'UNABLE_TO_WRITE_TARGET'
      bytes←0
    :EndTrap
    Log.Log(⌘bytes),' bytes written to ',tgt
  :Endif
▽

```


In this context the `:Trap` structure has an advantage over `TRAP`. When it fires, and control advances to its `:Else` fork, the trap is immediately cleared. So there is no need explicitly to reset the trap to avoid an open loop.

The handling of error codes and messages can easily obscure the rest of the logic. Clarity is not always easy to find, but is well worth working for. This is particularly true where there is no convenient test for an error, only a trap for when it is encountered.

In such cases, it is tempting to use a `:Return` statement to abort the function. But it can be confusing when a function ‘aborts’ in the middle, and we have learned a great respect for our capacity to get confused. Aborting from the middle of a function may also skip essential tidying up at the end.

We meet this issue reading files, where we trap errors and abort within a loop. Note how the use of `while/until` allows – unlike a `for` loop – to test at the ends of the loop both the counter and the exit code.

Rather than simply reporting an error in the file operation, you might prefer to delay a fraction of a second, then retry, perhaps two or three times, in case the problem is ephemeral and clears quickly.

This is in fact a deep topic. Many real-world problems can be treated by fix-and-resume when running under supervision, ie with a UI. Out of disk space? Offer the user a chance to delete some files and resume. But at this point we’re working ‘headless’ – without a UI – and the simplest and lightest form of resilience will serve for now.

We’ll provide this in the form of a `retry` operator. This will catch errors in its operand (monadic or dyadic) and retry up to twice at 500-msec intervals.

```

retry←{
  α←¬
  0::α αα ω¬DL .5
  0::α αα ω¬DL .5
  α αα ω
}

```

The `αα` in `retry` marks it as an operator, modifying how a function works. `αα` refers to the function. Assigning `¬` as the default value of `α` makes the operator *ambivalent*: it can modify dyadic functions as well as monadic functions. The error guard `0::` means *in the event of any error*. We use `retry` to modify the file reads and writes in `CountLettersIn`:

```

(txt enc nl)←NGET retry i>files
...
bytes←(lines enc nl)NPUT retry tgt C.NPUT.OVERWRITE

```

The `retry` operator goes into `#.MyApp`, not `#.Utilities`, because its strategy of two-more-tries is specific to this application.

Unforeseen errors

Our code so far covers the errors we foresee: errors in the parameters, and errors encountered in the file system. There remain the unforeseen errors, chief among them errors in our own code. If the code we have so far breaks, the EXE will try to report the problem to the session, find no session, and abort with an exit code of 4 to tell Windows “Sorry, it didn’t work out.”

If the error is easily replicable, we can easily track it down using the development interpreter. But the error might not be easily replicable. It could, for instance, have been produced by ephemeral congestion on a network interfering with file operations. Or the parameters for your app might be so complicated that it is hard to replicate the environment and data with confidence. What you really want for analysing the crash is a crash workspace, a snapshot of the ship before it went down.

For this we need a high-level trap to catch any event not trapped by `CountLettersIn`. We want it to save the workspace for analysis. We might also want it to report the incident to the developer – users don’t always do this! For this we’ll use the `HandleError` class from the `APLTree`.

Edit `Z:\code\v03\MyApp.dyapp`:

```
Target #
Load ..\AplTree\APLTreeUtils
Load ..\AplTree\FilesAndDirs
Load ..\AplTree\HandleError
Load ..\AplTree\Logger
Load Constants
Load Utilities
Load MyApp
Run MyApp.SetLX
```

And set an alias `H` for it in the preamble of the `MyApp` namespace:

```
(A F H L)←#.(APLTreeUtils FilesAndDirs HandleError Logger) H from APLTree
```

Define a new exit code constant:

```
OK←0
APPLICATION_CRASHED←100
INVALID_SOURCE←101
```

100? Why not 4, the standard Windows code for a crashed application? The distinction is useful. An exit code of 100 will tell us MyApp's trap caught and reported the crash. An exit code of 4 tells you even the trap failed!

We want the high-level trap only when we're running headless, so we'll start as soon as `StartFromCmdLine` begins, setting `HandleError` to do whatever it can before we can give it more specific information derived from the calling environment.

```

▽ StartFromCmdLine;exit;args
  A Read command parameters, run the application
  A trap unforeseen problems
  □TRAP←0 'E' '#.HandleError.Process ''''
  args←□2 □NQ'.' 'GetCommandLineArgs'
  Off TxtToCsv 2⇒2↑args
▽

```

This trap will do to get things started and catch anything that falls over immediately. We need to get more specific now in `TxtToCsv`. Before getting to work with `CheckAgenda`, refine the global trap definition:

```

...
LogError←Log◦{code←EXIT±ω ◊ code→α.LogError code ω}

isDev←#.A.IsDevelopment
A refine trap definition
#.ErrorParms←H.CreateParms
#.ErrorParms.errorFolder←F.PWD
#.ErrorParms.returnValue←EXIT.APPLICATION_CRASHED
#.ErrorParms.(logFunctionParent logFunction)←Log'Log'
#.ErrorParms.trapInternalErrors←~isDev
:If isDev
  □TRAP←0p□TRAP
:Else
  □TRAP←0 'E' '#.HandleError.Process ''#.ErrorParms'''
:EndIf

:If EXIT.OK⇒(exit files)←CheckAgenda fullfilepath
...

```

`CheckAgenda` and `CountLettersIn` are as before.

The test for `isDev` determines whether (true) the application is allowed to suspend, or (false) errors are to be caught and handled. Later we will set this in an INI file. For now we set it by testing whether the interpreter is development or runtime.

`#.ErrorParms.errorFolder` – write crash files as siblings of the EXE.

`#.ErrorParms.(logFunctionParent logFunction)` – we set a ref to the `Logger` instance, so `HandleError` can write on the log.

Test the global trap

We can test this! Put a full stop⁷ in the first few lines of `CountLettersIn`.

```
tbl←0 2ρ'A' 0
exit←EXIT.OK ♦ i←1
. A DEBUG
```

This will definitely break. It is not caught by any of the other traps.

Save the change. In the session, run

```
`#.MyApp.TxtToCsv 'Z:\texts\en'`
```

See that `CountLettersIn` suspends on the new line. This is just as you want it. The global trap does not interfere with your development work.

Now export the workspace to `Z:\code\v03\myapp.exe` and run it from the DOS command shell in `Z:\code\v03`:

```
Z:\code\v03>myapp.exe Z:\texts\en
```

```
Z:\code\v03>echo Exit Code was %errorcode%
Exit Code was 100
```

and what do we get?

Predictably we get no new result CSV. In `Z:\code\v03\Logs`, we find in the LOG a record of what happened.

First, the log entry records the crash then breaks off:

⁷The English poets among us love that the tersest way to bring a function to a full stop is to type one. (American poets will of course have typed a period and will think of it as calling time out.)

```

2016-05-13 10:56:28 *** Log File opened
2016-05-13 10:56:28 (0) Started MyApp in Z:\code\v03
2016-05-13 10:56:28 (0) Source: Z:\texts\en
2016-05-13 10:56:28 (0) Target: Z:\texts\en.CSV
2016-05-13 10:56:28 (0) *** Error
2016-05-13 10:56:28 (0) Error number=2
2016-05-13 10:56:28 (0) SYNTAX ERROR
2016-05-13 10:56:28 (0) CountLettersIn[4] . A DEBUG
2016-05-13 10:56:28 (0) ^

```

We also have an HTM with a crash report, an eponymous DWS containing the workspace saved at the time it broke, and an eponymous DCF whose single component is a namespace of all the variables defined in the workspace. Some of this has got to help.

However, the crash files names are simply the timestamp prefixed by an underscore:

```

Z:/code/v03/_20160513105628.dcf
Z:/code/v03/_20160513105628.dws
Z:/code/v03/_20160513105628.html

```

We can improve this by setting the Workspace Identification at launch time.

```

▽ StartFromCmdLine;exit;args
  A Read command parameters, run the application
  A trap unforeseen problems
  □TRAP←0 'E' '#.HandleError.Process ' ' '
  □WSID←'MyApp'
  args←□2 □NQ'.' 'GetCommandLineArgs'
  exit←TxtToCsv 2>2args
  □OFF exit
▽

```

Export the EXE again and run

```
Z:\code\v03>MyApp.exe Z:\texts\en
```

Now your crash files will have better names:

```
Z:/code/v03/MyApp_20160513112024.dcf
Z:/code/v03/MyApp_20160513112024.dws
Z:/code/v03/MyApp_20160513112024.html
```

Remove the deliberate error from `#.MyApp`, save your work and re-export the EXE.

Crash files

What's *in* those crash files?

The HTML contains a report of the crash and some key system variables:

MyApp_20160513112024

```
Version:           Windows 15.0.27377.0 W Runtime
❏WSID:
❏IO:              1
❏ML:              1
❏WA:              16408308
❏TNUMS:           0
Category:
EM:               SYNTAX ERROR
HelpURL:
EN:               2
ENX:              0
InternalLocation:  parse.c 1722
Message:
OSError:          0 0
Current Dir:      Z:\code\v03
Stack:
```

```
#.HandleError.Process[17]
#.MyApp.CountLettersIn[4]
#.MyApp.TxtToCsv[30]
#.MyApp.StartFromCmdLine[5]
Error Message:
```

```
SYNTAX ERROR
CountLettersIn[4] . A DEBUG
      ^
```

More information is saved in a single component – a namespace – on the DCF.

```

      'Z:/code/v03/MyApp_20160513112024.dcf'  FTIE 1
      FSIZE 1
1 2 7300 1.844674407E19
      q←FREAD 1 1
      q.NL 110
AN
Category
CurrentDir
DM
EM
EN
ENX
HelpURL
InternalLocation
LC
Message
OSError
TID
TNUMS
Trap
Vars
WA
WSID
XSI

      q.Vars.NL 2
ACCENTS
args
exit
files
fullfilepath
i
isDev
tbl
tgt

```

The DWS is the crash workspace. Load it. The Latent Expression has been disabled, to ensure MyApp does not attempt to start up again.

```

    )LX
    ⚡TRAP←0 'S' ⚡# MyApp.StartFromCmdLine

```

The State Indicator shows the workspace captured at the moment the `HandleError` object saved the workspace. Your problem – the full stop in `MyApp.CountLettersIn` – is two levels down in the stack.

```

    )SI
    #.HandleError.SaveErrorWorkspace[6]*
    #.HandleError.Process[23]
    #.MyApp.CountLettersIn[4]*
    #.MyApp.TxtToCsv[30]
    #.MyApp.StartFromCmdLine[5]

```

You can clear `HandleError` off the stack with a naked branch arrow. When you do so, you'll find the original global trap restored. Disable it. Otherwise any error you produce while investigating will trigger `HandleError` again!

```

    →
    )SI
    #.MyApp.CountLettersIn[4]*
    #.MyApp.TxtToCsv[30]
    #.MyApp.StartFromCmdLine[5]
    ⚡TRAP
    0 E #.HandleError.Process '#.ErrorParms'
    ⚡←⚡TRAP←0/⚡TRAP

```

In development you'll discover and fix most errors while working from the APL session. Unforeseen errors encountered by the EXE will be much rarer. Now you're all set to investigate them!

Configuration settings

Right now our MyApp program counts only Latin letters, ignores case and maps accented characters to their unaccented correspondents. That makes it of less use for French and German texts and of no use at all for Greek or Japanese texts. Other alphabets are possible. They could be supplied with the EXE as alphabet DATs and selected with command-line options. The user could supplement them with her own alphabet DATs. The default alphabet could be any one of the alphabet DATs. Or we might store all the alphabets as a single XML document.

Thinking more widely, an application's configuration includes all kinds of state: e.g., window positions, recent filepaths, and GUI themes.

In the chapter on Logging, we considered the question of where to keep application logs. The answer depends in part on what kind of application you are writing. Will there be single or multiple instances? For example, while a web browser might have several windows open simultaneously, it is nonetheless a single instance of the application. Its user wants to run just one version of it, and for it to remember her latest preferences and browsing history. But a machine may have many users, and each user needs her own preferences and history remembered.

Our MyApp program might well form part of other software processes, perhaps running as a service. There might be multiple instances of MyApp running at any time, quite independently of each other, each with quite different configuration settings.

Where does that leave us? We want configuration settings:

As defaults for the application in the absence of any other configuration settings

These must be coded into the application, so it will run in the absence of any configuration files. But an administrator should be able to revise these settings for a site. So they should be saved somewhere for all users. This filepath is represented in Windows by the `ALLUSERSPROFILE` environment variable. So we might look there for a `MyApp\MyApp.ini` file.

As part of the user's profile

The Windows environment variable `USERPROFILE` points to the individual user's profile, so we might look there for a `MyApp\MyApp.ini` file.

For invocation when the application is launched.

We can look in the command line arguments for an INI.

From the above we get a general pattern for configuration settings:

1. Set from program code
2. Overwrite from `ALLUSERSPROFILE` if any
3. If INI in command line, overwrite from it; else overwrite from `USERPROFILE`

Using the Windows Registry

The Windows Registry is held in memory, so it is fast to read. It has been widely used to store configuration settings. Many would say *abused*. We follow a consensus opinion that it is well to minimise use of the Registry.

Settings needed by Windows itself *have* to be stored in the Registry. For example, associating a file extension with your application, so that double clicking on its icon launches your application.

The APLTree class [WinReg](http://aplwiki.com/WinReg)⁸ provides methods for handling the Windows Registry.

MyApp doesn't need the Windows Registry at this point. We'll store its configurations in configuration files.

INI, JSON, or XML configuration files?

Three formats are popular for configuration files: INI, JSON and XML. INI is the oldest, simplest, and most crude. The other formats offer advantages: XML can represent nested data structures, and JSON can do so with less verbosity. Both XML and JSON depend upon unforgiving syntax: a single typo in an XML document can render it impossible to parse.

We want configuration files to be suitable for humans to read and write, so you might consider the robustness of the INI format an advantage. Or a disadvantage: a badly-formed XML document is easy to detect, and a clear indication of an error.

Generally, we prefer simplicity and recommend the INI format where it will serve.

Parameters for MyApp

We'll introduce some choices for MyApp that can then be set by configuration parameters.

ACCENTED

A flag to control whether accented characters are distinguished, or mapped to their unaccented forms. By default, this will be off.

ALPHABETS

We'll furnish MyApp with a repertoire of named alphabets, and allow more alphabets to be defined in configuration files.

ALPHABET

By default, MyApp will use the English alphabet. But we'll allow another default language to be configured.

⁸<http://aplwiki.com/WinReg>

OUTPUT

Output has so far been to a CSV eponymous with and sibling to the source. Now that can be specified.

SOURCE

So far, the source files have been specified either in the APL session, or in the Windows command line. But it might be convenient for a program calling `MyApp.exe` to specify everything in an INI file, so we'll make the source a configurable parameter.

Configuration *à la mode*

Distinguish two modes in which we run the MyApp code:

Application mode

The exported EXE is run from the Windows command line.

Session mode

The application has been assembled by the DYAPP and is being run in the development interpreter.

The mode will determine where we look for configuration parameters.

Sources of configuration parameters

Program code

We want MyApp to run in the absence of any external configuration parameters. So the program code must provide default values for all parameters.

User profiles

Windows provides filepaths for profiles for both individual users and all users.

In Application mode, the All Users profile is consulted for defaults.

In Session mode, the User profile is consulted for defaults.

Command line

In Application mode, any parameter specified in the command line supersedes other values for that parameter.

```
Z:\code\v04\>MyApp.exe ALPHABET=French ACCENTED=No Z:\texts\fr
```

In Session mode, we ignore parameters set on the command line, assuming that they relate to the Dyalog development environment.

We might also call `MyApp.exe` specifying only an INI of configuration parameters:

```
Z:\code\v04>type M:\jobqueue\job008.ini
ALPHABET=French
ACCENTED=No
SOURCE=M:\texts\Rimbaud.txt
Z:\code\v04>MyApp.exe J:\queue\job008.ini OUTPUT=J:\results\out008.csv
```

Or we might use INIs as job ‘profiles’, for example:

```
Z:\code\v04>type M:\profiles\p06.ini
ALPHABET=French
ACCENTED=No
Z:\code\v04>MyApp.exe J:\profiles\p06.ini SOURCE=M:\texts\Rimbaud.txt OUTPUT=J:\\
results\out008.csv
```

Manifest

Here’s our manifest for Version 4: `MyApp.dyapp`:

```
Target #
Load ..\AplTree\APLTreeUtils
Load ..\AplTree\FilesAndDirs
Load ..\AplTree\HandleError
Load ..\AplTree\IniFiles
Load ..\AplTree\Logger
Load Constants
Load Utilities
Load MyApp
Run MyApp.Start 'Session'
```

We’ve included `IniFiles` to the DYAPP’s build list. We’ll use `IniFiles` to handle INI files.

ADOC is useful for reading a class’s documentation. The `APLTree` library scripts all have ADOC documentation. You can read it in a browser:


```

    =/>"p.ALPHABETS.(English French)  A A is A
1
    =/>"p.ALPHABETS.(English Greek)   A A is not Alpha
0

```

Setting values in the program code ensures MyApp.exe will be able to run in the absence of any external INIs.

Now we see what is on the command line that called it, and look around for other INIs.

```

args←⊂2 ⍵NQ'. ' 'GetCommandLineArgs'    A Command Line
env←U.GetEnv                             A Windows Environment

A An INI for this app as a sibling of the EXE
fromexe←(⊃⍵NPARTS>args),⍵WSID, '.INI' A first arg is source of EXE
A First INI on the command line, if any
fromcmdline←{×≠ω:⊃ω ⍵ ' '}{ω/⍵'.INI'⍵≡""⍵4↑ω}(1↓args)
A An INI for this app in the ALLUSERS profile
fromallusers←env.ALLUSERSPROFILE, '\', ⍵WSID, '.INI'
A An INI for this app in the USER profile
fromuser←env.USERPROFILE, '\', ⍵WSID, '.INI'

```

That identifies four possible INIs we might read. Which ones we consult depends on the mode:

```

:Select mode
:Case 'Application'
    paths←fromexe fromallusers fromcmdline
:Case 'Session'
    paths←fromexe fromallusers fromuser
:EndSelect

```

Case and configuration parameters

It looks like we're almost there with configuration parameters. We can create an instance of IniFiles. Its `Convert` method will take a list of INIs, and return a namespace of parameters, with conflicts between the INIs resolved.

But case gets in the way.

Windows is case-insensitive, so `ALPHABET=FRENCH`, `alphabet=french`, and `Alphabet=French` should be equivalent. Any of them has to be interpreted to set the APL variable `alphabet`: in APL, case matters. So we'll loop through the paths.

We have already defined some alphabets `English`, `French` etc, so we'll set a convention that alphabet names are in title case.

```

:For path :In {ω/~/NEXISTS''ω}{ω/~/×#''U.trim''ω}paths
  A Allow INI entries to be case-insensitive
  ini←NEW #.IniFiles(,cpath)
  vars←U.m2n ini.␣NL 2
  :For parm :In {ω/~/ini.Exist''Config:'∘,''ω}PARAMS
    A Alphabet names are title case, eg Greek
    Δ←ini.Get'Config:',parm
    parm p.{⊂α,'←ω'}U.toTitlecase*(parm='alphabet') Δ
  :EndFor

:If ini.Exist'Alphabets:'
  Δ←(ini.Convert ␣NS'') A breaks if keys are not valid APL names
  a←Δ.⊂ALPHABETS'U.ciFindin U.m2n Δ.␣NL 9
  A Alphabet names are title case, eg Russian
  Δ←,' ',a.␣NL 2 A alphabet names
  (U.toTitlecase Δ)p.ALPHABETS.{⊂α,'←ω'}a⊂Δ
:EndIf
:EndFor

```

For this we've put new functions into `#.Utilities`: *m2n* *matrix to nest*, *ciFind* *case-independent find*, and *toTitlecase*. You can also observe the use of the *power* operator `*` instead of an if/else control structure.

Finally, in Application mode, we check the command line for any parameters set directly:

```

:If mode≡'Application' A set params from the command line
:AndIf ×#a←{ω/~/='∘'ω}args
  Δ←a⊂''='∘ (k v)←((Δ-1)↑''a)((Δ+1)↓''a)
  Δ←(≠PARAMS)≥i←⊂/U.toUppercase''PARAMS k
  (≠PARAMS[Δ/i]) p.{⊂α,'←ω'} Δ/v
:EndIf

```

Checking the agenda

Now that configuration parameters can be specified in INIs, there is more to check. So we pass the entire namespace of parameters to `CheckAgenda` as a left argument. `CheckAgenda` deploys a new error code – for an invalid alphabet name – and extends its result also to return the collation alphabet, with or without accented characters.

```

▽ (exit files alphabet)←params CheckAgenda ffp;fullfilepath;type
(files alphabet)←'' '' A error defaults
fullfilepath←F.NormalizePath ffp
type←C.NINFO.TYPE []NINFO fullfilepath
:If 0≠fullfilepath~' '
:OrIf ~[]NEXISTS fullfilepath
    exit←LogError'SOURCE_NOT_FOUND'
:ElseIf ~type∈C.NINFO.TYPES.(DIRECTORY FILE)
    exit←LogError'INVALID_SOURCE'
:ElseIf 2≠params.(ALPHABETS.[]NC alphabet)
    exit←LogError'INVALID_ALPHABET_NAME'
:Else
    exit←EXIT.OK
:Select type
:Case C.NINFO.TYPES.DIRECTORY
    files←>([]NINFO[]'Wildcard' 1)fullfilepath,'\*.txt'
:Case C.NINFO.TYPES.FILE
    files←<,cfullfilepath
:EndSelect
alphabet←params.{(ALPHABETS_αalphabet)~(~accented)/ω}ACCENTS[1;]
:EndIf
▽

```

Initialising the workspace

Checking the agenda requires more or less the same work whether we are starting in Session or in Application mode. That's why the DYAPP (see above) now finishes with:

```
Run MyApp.Start 'Session'
```

The validated configuration parameters will be set in a namespace `MyApp.Params`:

```

▽ Start mode;exit
A Initialise workspace for session or application
A mode: ['Application' | 'Session']
:If mode≡'Application'
    A trap problems in startup
    []TRAP←0 'E' '#.HandleError.Process ''''
:EndIf

```



```

WSID←'MyApp'
Params←GetParameters mode
:Select mode
:Case 'Session'
  α←'Alphabet is ',Params.alphabet
  α←'Defined alphabets: ',⌞U.m2n Params.ALPHABETS.⌞NL 2
  #.⌞LX←'#.MyApp.Start ''Application'' A ready to export
:Case 'Application'
  exit←TxtToCsv Params.source
  Off exit
:EndSelect
▽

```

What we think about when we think about encapsulating state

The configuration parameters are set in `Start` but the `Params` namespace is not passed explicitly to `TxtToCsv`. Perhaps `TxtToCsv` just refers to `Params`?

```

▽ exit←TxtToCsv fullfilepath;Δ;Log;LogError;files;tgt;alpha
...

:If EXIT.OK⇒(exit files alpha)←Params CheckAgenda fullfilepath
  Log.Log'Target: ',tgt←(⇒,/2↑⌞NPARTS fullfilepath),'.CSV'
  exit←alpha CountLettersIn files tgt
:EndIf
Log.Log'All done'
▽

```

Yes, that's it. Bit of a compromise here. Let's pause to look at some other ways to write this:

- Let `TxtToCsv` ignore `Params`. It doesn't read or set the contents. `CheckAgenda` can read `Params` instead. But, where we can, we avoid passing information through globals and 'semiglobals'. The exact opposite practice is to pass everything through function arguments. There is no appreciable performance penalty for this. The interpreter doesn't make 'deep copies' of the arguments unless and until they are modified in the called function (which we hardly ever do) – instead the interpreter just passes around references to the original variables.
- So we could pass `Params` as a left argument of `TxtToCsv`, which then simply gets passed to `CheckAgenda`. No performance penalty for this, as just explained, but now we've loaded the

syntax of `TxtToCsv` with a namespace it makes no direct use of, an unnecessary complication of the writing. And we've set a left argument we (mostly) won't want to specify when working in Session mode. We could make this left argument optional, taking `#.MyApps.Params` as its default. The cost of that is an if/else control statement, setting a value that, er, `TxtToCsv` still isn't reading or setting for itself. (And if we did want to set a left argument for `TxtToCsv` to use in Session mode, it would probably be the name of an alphabet...

The matter of *encapsulating state* – which functions have access to state information, and how it is shared between them – is very important. Poor choices can lead to tangled and obscure code.

From time to time you will be offered (not by us) rules that attempt to make the choices simple. For example: *never communicate through globals*. (Or semi-globals.⁹) There is some wisdom in these rules, but they masquerade as satisfactory substitutes for thought, which they are not. Just as in a natural language, any rule about writing style meets occasions when it can and should be broken. Following style 'rules' without considering the alternatives will from time to time have horrible results, such as functions that accept complex arguments only to pass them on unexamined to other functions.

Think about the value of style 'rules' and learn when to apply them.

Sometimes it's only after writing many lines of code that it becomes apparent that a different choice would have been better. And sometimes it becomes apparent that the other choice would be so much better that it's worth unwinding and rewriting a good deal of what you've done. (Then be glad you're writing in a terse language.)

We share these musings here so you can see what we think about when we think about encapsulating state; and also that there is often no clear right answer. Think hard, make your best choices, and be ready to unwind and remake them later if necessary.

Accents

We'll retain our map of accented to unaccented characters and convert any accented character *not in the alphabet* to its unaccented equivalent.

However, we'll suppose that the diacritical marks in classical Greek are not to distinguish different characters, so we'll extend the accents map to Greek:

```
Δ←' ÁÃÄÅÄÇÐÊËÉÍÎÏÑÒÓÔÕÖØÙÚÛÜÝÁÆΈήΉίϊΐΊόΌύΰΨΩ'
ACCENTS←↑Δ ' AAAAAACDEEEEIIIIINOOOOOUUUUYAAEEHHIIIIIOOYYYYΩ'
```

Note that for Greek this will map `Á` to the Greek Alpha, not the visually indistinguishable Roman A.

⁹So-called *semi-globals* are variables to be read or set by functions to which they are not localised. They are *semi-globals* rather than *globals* because they are local to either a function or a namespace. From the point of view of the functions that do read or set them, they are indistinguishable from *globals* – they are just mysteriously 'around'.

```

'.*'[1+#.MyApp.(ACCENTS€Params.ALPHABETS.Greek)]
.....
.....*****

```

Where and how shall we set the alphabet to be used? We start by revising `CountLetters` to take an alphabet as left argument. And now that the alphabet is explicit, it makes sense to sort the result into alphabetical order.

```

CountLetters←{
  accents←↓ACCENTS/˘~ACCENTS[2;]€α  α ignore accented chars in alphabet α
  α{ω[αΔω[;1];]}{α(≠ω)}⊔α{ω/˘ω€α}accents U.map U.toUppercase ω
}

```

Reality check. From [Project Gutenberg](http://www.projectgutenberg.org/)¹⁰ save the UTF-8 text files for Homer's *Iliad* and *Odyssey* in Greek. Top and tail them in a text editor to remove the English-language header and licence. That will still leave a few stray Roman characters, and lots of line numbers:

```

)CS #.MyApp
#.MyApp
  #il←⇒NGET 'Z:\texts\gr\iliad.txt'
679693
  A D CountLetters`c il
B 1 0 1459
C 1 1 766
D 1 2 791
E 4 3 775
H 1 4 727
I 1 5 1749
K 1 6 455
L 5 7 444
O 6 8 359
P 1 9 316
R 2
S 2
T 2
V 1

```

But most of it is in the Greek alphabet:

¹⁰<http://www.projectgutenberg.org/>

```

        Params.ALPHABETS.Greek CountLetters i l
A 50459
B 4533
Г 8955
Δ 7535
E 29370
Z 2132
H 10347
Θ 5346
I 34425
K 20629
Λ 13520
M 16659
N 28182
Ξ 2655
O 41993
Π 17518
P 21353
Σ 38822
T 41108
Υ 14682
Φ 6165
X 7085
Ψ 794
Ω 5877

```

Putting it together

For our first ‘sea trial’ we’ll use an INI file to define the Russian alphabet, and specify it to count the letter frequency in a [poem by Pushkin](#)¹¹.

One INI should define everything we need:

```

[CONFIG]
ALPHABET=RUSSIAN
SOURCE=Z:\TEXTS\PUSHKIN.TXT
[ALPHABETS]
RUSSIAN=АБВГДЕЁЖЗИЙКЛМНОПРСТУФХЦЧШЩЪЫЬЭЮЯ

```

Happily, Wikipedia assures us we have no accented characters to handle.

We’ll save the INI in the All-users Profile:

¹¹<http://www.gutenberg.org/ebooks/5316>

```
□CMD 'echo %allusersprofile%'  
C:\ProgramData
```

i.e. in C:\ProgramData\MyApp.ini and test in Session mode.

```
clear ws  
Booting Z:\code\v04\MyApp.dyapp  
Loaded: #.APLTreeUtils  
Loaded: #.FilesAndDirs  
Loaded: #.HandleError  
Loaded: #.IniFiles  
Loaded: #.Logger  
Loaded: #.Constants  
Loaded: #.Utilities  
Loaded: #.MyApp  
Alphabet is Russian  
Defined alphabets: English French German Greek Russian  
MyApp.TxtToCsv 'Z:\texts\ru'  
0
```

And the result? In Z:\texts\ru.csv:

```
A,109  
Б,22  
В,57  
Г,19  
Д,32  
Е,101  
Ж,13  
З,16  
И,61  
Й,29  
К,48  
Л,45  
М,30  
Н,75  
О,99  
П,34  
Р,58  
С,76  
Т,87  
У,42
```

Φ, 2
Χ, 14
Ц, 4
Ч, 10
Ш, 12
Щ, 6
Ѡ, 31
Ѣ, 18
Э, 2
Ю, 7
Я, 26

Looks like a win.

Testing: the sound of breaking glass

Our application here is simple – just count letter frequency in text files.

All the other code has been written to package the application for shipment, and to control how it behaves when it encounters problems.

Developing code refines and extends it. We have more developing to do. Some of that developing might break what we already have working. Too bad. No one's perfect. But we would at least like to know when we've broken something – to hear the sound of breaking glass behind us. Then we can fix the error before going any further.

In our ideal world we would have a team of testers continually testing and retesting our latest build to see if it still does what it's supposed to do. The testers would tell us if we broke anything. In the real world we have programs – tests – to do that.

What should we write tests for? “Anything you think might break,” says Kent Beck¹², author of *Extreme Programming Explained*. We've already written code to allow for ways in which the file system might misbehave. We should write tests to discover if that code works. We'll eventually discover conditions we haven't foreseen and write fixes for them. Then those conditions too join the things we think might break, and get added to the test suite.

Why you want to write tests

Notice when you break things

Some functions are more vulnerable than others to being broken under maintenance. Many functions are written to encapsulate complexity, bringing a common order to a range of different arguments. For example, you might write a function that takes as argument any of a string¹³, a vector of strings, a character matrix or a matrix of strings. If you later come to define another case, say, a string with embedded line breaks, it's easy enough inadvertently to change the function's behaviour with the original cases.

If you have tests that check the function's results with the original cases, it's easy to ensure your changes don't change the results unintentionally.

¹²Kent Beck, in conversation with one of the authors.

¹³APL has no *string* datatype. We use the word as a casual synonym for *character vector*.

More reliable than documentation

No, tests don't replace documentation. They don't convey your intent in writing a class or function. They don't record your ideas for how it should and should not be used, references you consulted before writing it, or thoughts about how it might later be improved.

But they do document with crystal clarity what it is *known* to do. In a naughty world in which documentation is rarely complete and even less often revised when the code is altered, it has been said the *only* thing we know with certainty about any given piece of software is what tests it passes.

Understand more

Test-Driven Design (TDD) is a high-discipline practice associated with Extreme Programming. TDD tells you to write the tests *before* you write the code. Like all such rules, we recommend following TDD thoughtfully. The reward from writing an automated test is not *always* worth the effort. But it is a very good practice and we strongly recommend it.

If you are writing the first version of a function, writing the tests first will clarify your understanding of what the code should be doing. It will also encourage you to consider boundary cases or edge conditions: for example, how should the function above handle an empty string? A character scalar? TDD first tests your understanding of your task. If you can't define tests for your new function, perhaps you're not ready to write the function either.

If you are modifying an existing function, write new tests for the new things it is to do. Run the revised tests and see that the code fails the new tests. If the unchanged code *passes* any of the new tests... review your understanding of what you're trying to do!

Write better

Writing functions with a view to passing formal tests will encourage you to write in *functional style*. In pure functional style, a function reads only the information in its arguments and writes only its result. No side effects or references.

```

▽ Z←mean R;r
[1] Z←((+/r)÷#r←,R)
▽

```

In contrast, this line from `TxtToCsv` reads a value from a namespace external to the function (`EXIT.APPLICATION_CRASHED`) and sets another: `#.ErrorParms.returnCode`.

```

#.ErrorParms.returnCode←EXIT.APPLICATION_CRASHED

```


In principle, `TxtToCsv` *could* be written in purely functional style. References to classes and namespaces `#.HandleError`, `#.APLTreeUtils`, `#.FilesAndDirs`, `EXIT`, and `#.ErrorParms` could all be passed to it as arguments. If those references ever varied – for example, if there were an alternative namespace `ReturnCodes` sometimes used instead of `EXIT` – that might be a useful way to write `TxtToCsv`. But as things are, cluttering up the function’s *signature* – its name and arguments – with these references harms rather than helps readability. It is an example of the cure being worse than disease.

You can’t write *everything* in pure functional style but the closer you stick to it, the better your code will be, and the easier to test. Functional style goes hand in hand with good abstractions, and ease of testing.

Why you don’t want to write tests

There is nothing magical about tests. Tests are just more code. The test code needs maintaining like everything else. If you refactor a portion of your application code, the associated tests need reviewing – and possibly revising – as well. In programming, the number of bugs is generally a linear function of code volume. Test code is no exception to this rule. Your tests are both an aid to development and a burden on it.

You want tests for everything you think might break, but no more tests than you need.

Beck’s dictum – test anything you think might break – provides useful insight. Some expressions are simple enough not to need testing. If you need the indexes of a vector of flags, you can *see* that `{ω/ι≠ω}` will find them. It’s as plain as $2+2$ making four. You don’t need to test that. APL’s scalar extension and operators such as *outer product* allow you to replace nested loops (a common source of error) with expressions which don’t need tests. The higher level of abstraction enabled by working with collections allows not only fewer code lines but also fewer tests.

Time for a new version of MyApp. Make a copy of `Z:\code\v04` as `Z:\code\v05`.

Setting up the test environment

We’ll need the `Tester` class from the `APLTree` library. And a namespace of tests, which we’ll dub `#.Tests`.

Write `Z:\code\v05\Tests.dyalog`:

```
:Namespace Tests
A Dyalog Cookbook, Version 05
A Tests
A Vern: sjt24jun16

:EndNamespace
```

and include both scripts in the DYAPP:

```
Target #
Load ..\AplTree\APLTreeUtils
Load ..\AplTree\FilesAndDir
Load ..\AplTree\HandleError
Load ..\AplTree\IniFiles
Load ..\AplTree\Logger
Load ..\AplTree\Tester
Load Constants
Load Utilities
Load Tests
Load MyApp
Run MyApp.Start 'Session'
```

Run the DYAPP to build the workspace. In the session execute `Jadoc_browse #.Tester` to see the documentation for the Tester class, and browse also to aplwiki.com/Testers¹⁴ to see the discussion there.

Unit and functional tests

Unit tests tell a developer that the code is *doing things right*; functional tests tell a developer that the code is *doing the right things*.

It's a question of perspective. Unit tests are written from the programmer's point of view. Does the function or method return the correct result for given arguments? Functional tests, on the other hand, are written from the user's point of view. Does the software do what its *user* needs it to do?

Both kinds of tests are important. If you are a professional programmer you need a user representative to write functional tests. If you are a domain-expert programmer¹⁵ you can write both.

In this chapter we'll tackle unit tests. Later in the book we'll consider functional tests.

¹⁴<http://aplwiki.com/Testers>

¹⁵an expert in the domain of the application rather than an expert programmer, but who has learned enough programming to write the code.

The two-flag right argument is part of the signature of a test function. We'll come back to what the flags do. The result `Z` indicates `¬1`: the test broke ; `0`: no problem found; `1`: problem found.

Now the basic English alphabet, and the Latin and Greek accented characters

```

▽ Z←Test_toLowercase_003(debugFlag batchFlag)
  A base case
  Z←EN_lower≠#.Utilities.toLowercase A
▽

▽ Z←Test_toLowercase_004(debugFlag batchFlag)
  A accented Latin and Greek characters
  Z←AccentedLower≠#.Utilities.toLowercase AccentedUpper
▽

```

This is tedious already, but writing tests is all about being thorough, so we'll replicate these four tests for `toUpperCase` (reversing the arguments) and throw in a couple for `toTitlecase` as well.

```

A #.Utilities.toTitlecase

▽ Z←Test_toTitlecase_001(debugFlag batchFlag)
  A base case
  Z←'The Quick Brown Fox'≠#.Utilities.toTitlecase'the QUICK brown FOX'
▽

▽ Z←Test_toTitlecase_002(debugFlag batchFlag)
  A Greek script
  Z←'Όι Πολλοί'≠#.Utilities.toTitlecase'Όι ΠΟΛΛΟΪ'
▽

```

That will do as a start. Notice each test is defined as a function that returns a scalar flag indicating whether it has found an error. (Not whether it has passed.) No test has referred to any argument: we'll come back to that shortly.

Let's give these tests a run.

```

      #.Tester.Run #.Tests
--- Tests started at 2016-06-26 14:08:04 on #.Tests -----
    Test_toLowercase_001 (1 of 10) : boundary case
    Test_toLowercase_002 (2 of 10) : no case
    Test_toLowercase_003 (3 of 10) : base case
    Test_toLowercase_004 (4 of 10) : accented Latin and Greek characters
    Test_toTitlecase_001 (5 of 10) : base case
    Test_toTitlecase_002 (6 of 10) : Greek script
    Test_toUppercase_001 (7 of 10) : boundary case
    Test_toUppercase_002 (8 of 10) : no case
    Test_toUppercase_003 (9 of 10) : base case
* Test_toUppercase_004 (10 of 10) : accented Latin and Greek characters
-----
    10 test cases executed
    1 test case failed
    0 test cases broken

```

Ah. Now there's a surprise. Despite their simplicity, we already have a test that failed. Let's investigate.

```

      )CS #.Tests
#.Tests
    AccentedLower ≡ #.Utilities.{toLowercase toUppercase ω} AccentedLower
1
    AccentedUpper ≡ #.Utilities.{toUppercase toLowercase ω} AccentedUpper
0

```

So the problem is with `AccentedUpper`.

```

      where←{ω/ι≠ω}
      where AccentedUpper≠#.Utilities.{toUppercase toLowercase ω} AccentedUpper
33 35
      AccentedUpper[33 35]
óú

```

And there we have it. `AccentedUpper` includes two lowercase characters. Easy enough to miss if you're not familiar with Greek script. Easy enough to find and fix! Testing rocks. Redefine the accented character lists.

```

# accented Latin and Greek characters
AccentedUpper←'ÁÂÃÄÅÇÐÈÉÊËÌÍÎÏÑÒÓÔÕÖØÙÚÛÜÝÀÆΗΙΟΥΩ'
AccentedLower←'áâãäåçðèéêëìíîïñòóôõöøùúûüýàæήιόύώ'

```

Now our tests all pass. We'll proceed to something more substantial: `CountLetters`. A base case would run it against the English alphabet:

```

Params.ALPHABETS.English CountLetters 'The Quick Brown Fox'

B 1
C 1
E 1
F 1
H 1
I 1
K 1
N 1
O 2
Q 1
R 1
T 1
U 1
W 1
X 1

```

That result could be specified more conveniently as two columns.

```

↓[1]Params.ALPHABETS.English CountLetters 'The Quick Brown Fox'

```

BCEFHINOQRTUWX	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1
----------------	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

So our new section in `#.Tests` becomes

```

A #.MyApp.CountLetters

▽ Z←Test_CountLetters_001(debugFlag batchFlag);a;r
A base case
a←#.MyApp.Params.ALPHABETS.English
r←('BCEFHINOQRTUWX')(1 1 1 1 1 1 1 1 2 1 1 1 1 1)
Z←r≠↓[1]a #.MyApp.CountLetters'The Quick Brown Fox'
▽

```

Unit tests with state

You might have spotted some ‘state’ hidden in the last test. `CountLetters` refers to the matrix `ACCENTS` of accented characters. That table is a constant, so perhaps we can be allowed to say the last test is a stateless unit test.

The same cannot be true of the `CountLettersIn` function, which reads and writes files. The result depends on the state in the files.

At this point we need to incorporate files and folders into our test apparatus. We have suitable source folders and output files in `Z:\texts`, but we have a problem with using them as they are: we have no independent way of verifying the results for the contents.

Better to use shorter files for which the correct results can be determined independently. Best of all, let the tests generate the files.

The `Tester` class looks in the tests for a function called `Initial` and runs that first. We’ll use this convention to create test files with known character frequencies.

```

C←#.Constants
TEST_FLDR←'./tests/'
▽ Initial;C;file
:If ⚡NEXISTS TEST_FLDR
:For file :In ⚡C.NINFO.NAME(⚡NINFO⚡'Wildcard' 1)TEST_FLDR,'*.*'
⚡DELETE file
:EndFor
:Else
⚡MKDIR TEST_FLDR
:EndIf
▽
...

```

Why loop on `file` rather than `DELETE` the list of files? Because `DELETE` will break on an empty list.

```

▽ Z←Test_CountLettersIn_001(debugFlag batchFlag);a;files;cf;cc2n;sas;res
  A across multiple files
  a←#.MyApp.Params.ALPHABETS.English
  cc2n←{2 1○"VFII"2↓ω}                                A CSV col 2 as numbers
  res←(1↓TEST_FLDR),'.csv'                               A results file
  sas←{ω[?~≠ω]}                                         A scramble a string
  cf←?1000ρ~5,≠a                                         A random freqs for 5 files
  files←{TEST_FLDR,'test',ω,'.txt'}○≠i≠cf
  (sas"(↓cf)/"ca)NPUT"files
  :If Z←#.MyApp.EXIT.OK≠a #.MyApp.CountLettersIn files res
  :OrIf Z←(+≠cf)≠cc2n=NGET res 1
  :EndIf
▽

```

Admire how elegantly the notation lets us generate randomised character frequencies from alphabet `a` for 5 files (`?1000ρ~5,≠a`) and scramble them (`{ω[?~≠ω]}`).

But our elegant test breaks!

```

      #.Tester.EstablishHelpersIn #.Tests
      #.Tests.Run
--- Tests started at 2016-07-24 11:18:08 on #.Tests -----
# Test_CountLettersIn_001 (1 of 12) : across multiple files
  Test_CountLetters_001 (2 of 12) : base case
  Test_toLowercase_001 (3 of 12) : boundary case
  Test_toLowercase_002 (4 of 12) : no case
  Test_toLowercase_003 (5 of 12) : base case
  Test_toLowercase_004 (6 of 12) : accented Latin and Greek characters
  Test_toTitlecase_001 (7 of 12) : base case
  Test_toTitlecase_002 (8 of 12) : Greek script
  Test_toUppercase_001 (9 of 12) : boundary case
  Test_toUppercase_002 (10 of 12) : no case
  Test_toUppercase_003 (11 of 12) : base case

```



```
Test_toUppercase_004 (12 of 12) : accented Latin and Greek characters
```

```
-----
12 test cases executed
0 test cases failed
1 test case broken
```

Investigation reveals the problem:

```
        )CS #.Tests
#.Tests
    Initial
        Test_CountLettersIn_001 0 0
VALUE ERROR
CountLettersIn[21] Log.Log(⌘bytes),' bytes written to ',tgt
                ^
```

`Log` is undefined. In the envisaged use in production, it is defined by and local to `TxtToCsv`, the function that calls `CountLettersIn`. We have a similar issue with function `LogError`. That design followed Occam's Razor¹⁶: (entities are not to be needlessly multiplied) in keeping the log object in existence only while needed. But it now prevents us from testing `CountLettersIn` independently. So we'll refactor `Log` to be a child of `#.MyApp`, created by `Start`:

```
...
WSID←'MyApp'

'CREATE!'F.CheckPath'Logs' A ensure subfolder of current dir
Δ←L.CreatePropertySpace
Δ.path←'Logs',F.CurrentSep A subfolder of current directory
Δ.encoding←'UTF8'
Δ.filenamePrefix←'MyApp'
Δ.refToUtils←#
Log←NEW L(,Δ)

Log.Log'Started MyApp in ',F.PWD

LogError←Log◦{code←EXIT⊕ω ◊ code←α.LogError code ω}

Params←GetParameters mode
...
```

And `Initial` will call `#MyApp.Start 'Session'`.

Now we have both stateless and state-full tests passing. This completes Version 5.

¹⁶*Non sunt multiplicanda entia sine necessitate.*

Make me

It's time to take a closer look at the process of building the application workspace and exporting the EXE. In this chapter we'll

- split the DYAPP into separate versions – one to create the development and testing environment, the other to assemble and export the application;
- automate the export process;
- write tests for the EXE.

We resume, as usual, by saving a copy of `Z:\code\v05` as `Z:\code\v06`.

Make me whole, make me lean

Our makefile, `MyApp.dyapp`, includes scripts we have no reason to include in the exported EXE:

```
Target #
Load ..\AplTree\APLTreeUtils
Load ..\AplTree\FilesAndDirs
Load ..\AplTree\HandleError
Load ..\AplTree\IniFiles
Load ..\AplTree\Logger
Load ..\AplTree\Tester
Load Constants
Load Utilities
Load Tests
Load MyApp
Run MyApp.Start 'Session'
```

`Tester` and `Tests` have no place in the finished application.

We could expunge them before exporting the active workspace as an EXE. Or – have *two* makefiles, one for the development environment, one for export.

Duplicate `MyApp.dyapp` and name the files `Develop.dyapp` and `Export.dyapp`. Edit `Export.dyapp` as follows:

```

Target #
Load ..\AplTree\APLTreeUtils
Load ..\AplTree\FilesAndDirs
Load ..\AplTree\HandleError
Load ..\AplTree\IniFiles
Load ..\AplTree\Logger
Load Constants
Load Utilities
Load MyApp
Run MyApp.Start 'Export'

```

Now, `#.MyApp.Start` doesn't yet have an Export mode, so we'd better give it one:

```

...
:Select mode
:Case 'Export'
    #.LX←#.MyApp.Start ''Application'' A ready to export
:Case 'Session'
    ⍵←'Alphabet is ',Params.alphabet
    ⍵←'Defined alphabets: ',⍶U.m2n Params.ALPHABETS.⍵NL 2
:Case 'Application'
    exit←TxtToCsv Params.source
    Off exit
:EndSelect

```

Notice that Session mode no longer needs to set the Latent Expression.

Refactoring

We also notice now that the contents of `#.MyApp` divide into two groups. One is concerned with setting up the environment and communicating with the operating system. The other does the work of `MyApp`. We'll now refactor them into separate namespaces: `MyApp` and `Environment`.

`MyApp` will continue to contain the code for counting frequency. But the code for interrogating the environment, setting error traps, and starting logging – we'll move that into `Environment`. And we'll minimise the cross references between the two.

First, all the default parameter values for `MyApp` – the values it has to have in case they are set nowhere else – can go into a simple, static namespace:

```

:Namespace PARAMETERS
  :Namespace ALPHABETS
    English←[]A
    French←'AÁÂÃBCÇDEÈÉÊFGHIÎÏJKLMNOÒÓÔPQRSTUÙÚÛVWXYZ '
    German←'AÄBCDEFGHIJKLMNOÖPQRSBTUÜVWXYZ '
    Greek←'ΑΒΓΔΕΖΗΘΙΚΑΜΝΞΟΠΡΣΤΥΦΧΨΩ '
  :EndNamespace
  accented←0
  alphabet←'English'
  source←''
  output←''
:EndNamespace

```

We'll leave to `Environment` the definition of `MyApp.Params` and `MyApp.Log` and just make a note of that in `MyApp`:

`MyApp` Objects `Log` and `Params` are defined by `Environment.Start`

That lets us cut `MyApp` down to size:

```

)CS MyApp
#.MyApp
)FNS
CheckAgenda      CountLetters      CountLettersIn  TxtToCsv
)VARS
ACCENTS Δ

```

`Environment` will get the `Start` function. For extra clarity we'll rename the start modes to `Develop`, `Export` and `Run`.

```

▽ Start mode;Δ
MyApp Initialise workspace for development, export or use
MyApp mode: ['Develop' | 'Export' | 'Run']
  :If mode≡'Run`'
    MyApp trap problems in startup
    #.[]TRAP←0 'E' 'E' #.HandleError.Process ' '
  :EndIf
  []WSID←'MyApp'

```

It must now create the `Log` object 'over there' – within `MyApp`.

```

'CREATE!'#.FilesAndDirs.CheckPath'Logs' A ensure subfolder of current dir
Δ←{
    ω.path←'Logs',F.CurrentSep A subfolder of current directory
    ω.encoding←'UTF8'
    ω.filenamePrefix←'MyApp'
    ω.refToUtils←#
    ω
}#.Logger.CreatePropertySpace
#.MyApp.Log←NEW #.Logger(,Δ)

```

Read the arguments from the command line:

```

args←⊂2 ⊂NQ'.' 'GetCommandLineArgs' A command line
#.MyApp.Log.Log``('Command line arg ['∘,``(⊆⊂≠args),``c']: '),``args

```

Set the PARAMETERS namespace in #.MyApp:

```

#.MyApp.PARAMETERS GetParameters mode args env

```

While we're at this, we've switched the arguments in `GetParameters` to follow an ancient APL convention for functions, that the right argument represents data and any left argument, some modifier for the function.¹⁷

What happens next depends upon the mode. If we're getting ready to develop, we want tools and tests. We'll ensure global error trapping is off, so we can investigate any errors. And we might as well start by running the tests:

```

:Select mode

:Case 'Develop'
    #.⊂TRAP←0ρ#.⊂TRAP
    ⊂←'Alphabet is ',#.MyApp.PARAMETERS.alphabet
    ⊂←'Defined alphabets: ',⊆U.m2n #.MyApp.PARAMETERS.ALPHABETS.⊂NL 2
    #.Tester.EstablishHelpersIn #.Tests
    #.Tests.Run

```

If we're starting in Export mode, everything is ready to export as an EXE. We'll just display the expression that does that.

¹⁷the best example of this are the circle functions represented by ∘.

```
:Case 'Export'
  □←U.ScriptFollowing
  A Exporting to an EXE can fail unpredictably.
  A Retry the following expression if it fails,
  A or use the File>Export dialogue from the menus.
  A      #.Environment.Export '.\MyApp.exe'
```

We'll define that Export function in a moment. Right now, we'll set out what the EXE is to do when it runs:

```
:Case 'Run'
  #.ErrorParms←{
    ω.errorFolder←#.FilesAndDirs.PWD
    ω.returnValue←#.MyApp.EXIT.APPLICATION_CRASHED
    ω.(logFunctionParent logFunction)←(#.MyApp.Log)('Log')
    ω.trapInternalErrors←~#.APLTreeUtils.IsDevelopment
  }#.HandleError.CreateParms
  #.□TRAP←0 'E' ' #.HandleError.Process ' '#.ErrorParms''
  Off #.MyApp.TxtToCsv #.MyApp.Params.source
```

Now that Export function. You'll have noticed exporting an EXE can fail from time to time, and you've performed this from the *File* menu enough times to have tired of it. So we'll automate it. Automating it doesn't make it any more reliable, but it certainly makes retries easier.

```
▽ msg←Export filename;type;flags;resource;icon;cmdline;nl;success;try
  #.□LX←#.Environment.Start ''Run''

  type←'StandaloneNativeExe'
  flags←2 A BOUND_CONSOLE
  resource←''
  icon←F.NormalizePath '.\images\gear.ico'
  cmdline←''

  success←try←0
  :Repeat
    :Trap 11
      2 □NQ'.' 'Bind',filename type flags resource icon cmdline
      success←1
    :Else
      □DL 0.2
    :EndTrap
  :Until success∨50<try←+1
```

```

    msg←>successφ('**ERROR: Failed to export EXE')('Exported ',filename)
    msg,←(try>1)/' after ',(try),' tries'
    #.MyApp.Log.Log msg
▽

```

Basically, the choices you have been making from the *File > Export* dialogue, now wrapped as a function.

One last tweak to the setup for development. Let's have some handy tools defined in `#.MyApp` just for when we're working in there.

```

:Namespace DevTools
A Developer tools
A Vern: sjt25jul16

fc←{α(≠ω)}| A frequency count
same←{ω≡''c>ω}°,
type←{type←{'CN' [□IO+0=>0ρ>*≡ω]}}
wi←{(≡ω)(type ω)(ρω)} A what is this array?

:EndNamespace

```

A few tweaks now to the makefiles. `Develop.dyapp`:

```

Target #
Load ..\AplTree\APLTreeUtils
Load ..\AplTree\FilesAndDirs
Load ..\AplTree\HandleError
Load ..\AplTree\IniFiles
Load ..\AplTree\Logger
Load ..\AplTree\Tester
Load Constants
Load Tests
Load Utilities
Load MyApp
Load Environment
Target #.MyApp
Load DevTools -disperse
Run #.Environment.Start 'Develop'

```

Note the `Target #.MyApp` followed by `Load DevTools -disperse`. That disperses the contents of the `DevTools` namespace into `#.MyApp`. (Watch out for name conflicts if you do this.) Now when we're working in `MyApp` we'll have some tools to hand.

Running the DYAPP creates our working environment and runs the tests:

```

clear ws
Booting Z:\code\v06\Develop.dyapp
Loaded: #.APLTreeUtils
Loaded: #.FilesAndDirs
Loaded: #.HandleError
Loaded: #.IniFiles
Loaded: #.Logger
Loaded: #.Tester
Loaded: #.Constants
Loaded: #.Tests
Loaded: #.Utilities
Loaded: #.MyApp
Loaded: #.Environment
Loaded: * 4 objects dispersed in #.MyApp
Alphabet is Russian
Defined alphabets: English French German Greek Russian
--- Tests started at 2016-07-25 15:18:17 on #.Tests -----
  Test_CountLettersIn_001 (1 of 12) : across multiple files
  Test_CountLetters_001 (2 of 12) : base case
  Test_toLowercase_001 (3 of 12) : boundary case
  Test_toLowercase_002 (4 of 12) : no case
  Test_toLowercase_003 (5 of 12) : base case
  Test_toLowercase_004 (6 of 12) : accented Latin and Greek characters
  Test_toTitlecase_001 (7 of 12) : base case
  Test_toTitlecase_002 (8 of 12) : Greek script
  Test_toUppercase_001 (9 of 12) : boundary case
  Test_toUppercase_002 (10 of 12) : no case
  Test_toUppercase_003 (11 of 12) : base case
  Test_toUppercase_004 (12 of 12) : accented Latin and Greek characters
-----
  12 test cases executed
  0 test cases failed
  0 test cases broken

```

The foregoing is a good example of how having automated tests allows us to refactor code with confidence that we'll notice and fix anything we break.

Slight tweaks to the export makefile and we can export an EXE. `Export.dyapp`:


```
Target #
Load ..\AplTree\APLTreeUtils
Load ..\AplTree\FilesAndDirs
Load ..\AplTree\HandleError
Load ..\AplTree\IniFiles
Load ..\AplTree\Logger
Load Constants
Load Utilities
Load MyApp
Load Environment
Run #.Environment.Start 'Export'
```

Run this new export makefile and we get a new session:

```
clear ws
Booting Z:\code\v06\Export.dyapp
Loaded: #.APLTreeUtils
Loaded: #.FilesAndDirs
Loaded: #.HandleError
Loaded: #.IniFiles
Loaded: #.Logger
Loaded: #.Constants
Loaded: #.Utilities
Loaded: #.MyApp
Loaded: #.Environment
Exporting to an EXE can fail unpredictably.
Retry the following expression if it fails,
or use the File>Export dialogue from the menus.
    #.Environment.Export '.\MyApp.exe'
```

And if we execute the suggested expression...¹⁸

```
    #.Environment.Export '.\MyApp.exe'
Exported .\MyApp.exe
```

Testing the EXE

We've written tests for running MyApp from the session. We also need to test whether the EXE works too. We'll write `Test_Exe_001`.

¹⁸It would be great if `#.Environment.Export` could be run straight from the DYAPP. But the DYAPP has to finish before an EXE can be exported.

It's not enough to examine the exit code that MyApp.exe returns to Windows. We also need to examine the results. So our test will follow the same strategy used in `Test_CountLettersIn_001`: it will generate a set of test files and a corresponding result table. This time it will run the EXE, then see if the result file exists and holds the correct results.

We start by refactoring out of `Test_Count_LettersIn` the code to be shared with `Test_Exe_001`:

```

▽ failed←Test_CountLettersIn_001(debugFlag batchFlag)
  A across multiple files
  failed←testOnFiles'APL' 5 'English'
▽

▽ failed←testOnFiles(testmode nfiles alph) ;cd;files;res;cc2n;cf;xxx;alphabet;cmd
  EraseFilesIn TEST_FLDR
  alphabet←#.MyApp.PARAMETERS.ALPHABETS⊘alph
  cf←?1000p⊘nfiles,⊘alphabet                                A random freqs for nfile\
s files
  files←{TEST_FLDR,'test',ω,'.txt'}⊘⊘⊘nfiles                A full filenames
  ({ω[?~⊘ω]}''(↓cf)/''⊘alphabet)⊘NPUT''files
  res←(↑1↓TEST_FLDR),'.csv'                                  A result file

  :If ~failed←{~⊘NEXISTS ω:0 ⊘ ~⊘NDELETE ω}res
    :Select testmode
    :Case 'APL'
      failed←#.MyApp.EXIT.OK⊘alphabet #.MyApp.CountLettersIn files res
    :Case 'EXE'
      cmd←'.\myapp.exe source="'',TEST_FLDR,'" alphabet=',alph
      xxx←⊘CMD cmd
      failed←~⊘NEXISTS res
    :EndSelect
    :If ~failed
      cc2n←{2 1⊘>'⊘VFI''2↓''ω}                                A CSV col 2 as numbers
      failed←(+/cf)⊘cc2n⊘⊘NGET res C.NGET.LINES
    :EndIf
  :EndIf
▽

▽ EraseFilesIn folder
  :For file :In >C.NINFO.NAME(⊘NINFO⊘'Wildcard' 1)folder,'*.*'
    ⊘NDELETE file
  :EndFor
▽

```

As we can see, `testOnFiles` sets up the test files and results, then according to its argument, either runs `CountLettersIn` or launches the EXE.

Obvious to say but easy to overlook: after making any changes to the DYALOGs, export a new EXE to ensure that the EXE tests are testing the changes you just made. Then launch `Develop.dyapp` to run all the tests.

Workflow

With the two DYAPPs, your development cycle now looks like this:

1. Launch `Develop.dyapp` and review test results.
2. Fix any errors and rerun `#.Tests.Run`. (If you edit the test themselves, either rerun `#,Tester.EstablishHelpersIn #.Tests` or simply close the session and relaunch `Develop.dyapp`.)
3. Launch `Export.dyapp`, which will export a new EXE. Close the session.

The Doc is in

Testing in different versions of Windows

User interface – native

A simple UI with native Dyalog forms

Forms

Controls

Callbacks and the event queue

Extended controls

Providing help

(Choice between CHM generated by say *Help and Manual* or the APLTreeHelp namespace.)

Writing an installer

Working with other processes

Launching tasks

Running as a Windows service

Sharing files

Communicating through TCP/IP

Managing your source code

Documentation

FIRE

CompareSimple

Useful user commands

Storing data

Native and component files

XML

JSON

Relational databases

User interface – WPF

User interface – HTTP

Deploying as a Web application

Deploying as a Web service

2. Professional programming practices

Minimise semantic distance

Modern programs are much bigger as are machine memories. In general the scarcest resource is human attention. For the *human* reader, assigning a name to a value (defining a variable) equates to *remember this*. Remember this value, just calculated, by this name. The more such associations the reader has to remember, and the longer she has to remember them, the greater the demand, the cognitive load, upon the reader.

Semantic distance is the ‘distance’ in the code between assigning a variable and using it in another expression. Minimise the distance. Use the variable as soon as possible after setting it. Don’t ask your reader to remember an association over 10 lines of code if she need only remember it over two.

No names

The minimum semantic distance is zero. This is when you ‘use’ a value in the same expression in which you calculated it. If you can do this – and have no further need to refer to the value – then avoid assigning it a name at all. Even a short name, such as `x`, is a demand that the reader remember it until at least the end of the function.

You can often use anonymous D-functions (lambdas) within a function to avoid defining variables in it. Assignments *within* the D-function disappear when the D-function leaves the stack, so it’s clear the reader has nothing to remember.

For example, suppose you want to apply a function `foo` to the second element of the result of an expression before passing the lot onto another function `bar`. You might write:

```
triple←expression
(2>triple)←foo 2>triple
bar triple
```

But you can avoid defining `triple`, for which you have no further use and thus no need for the reader to remember, with an anonymous D-function:

```
bar {(a b c)←ω ◊ a (foo b) c} expression
```

Or even an operator:

```
bar 0 1 0 foo{ $\alpha\alpha^*\alpha\vdash\omega$ } ``expression
```

Delta, the Heraclitean variable

Sometimes you need a name even though your reader need remember it only until the next line. You might need multiple lines to construct an array:

```
 $\Delta \leftarrow$  ('Dog' 'Mammal') ('Cat' 'Mammal') ('Carp' 'Fish')
 $\Delta, \leftarrow$  ('Eagle' 'Bird') ('Viper' 'Reptile') ('Rabbit' 'Mammal')
RegisterAnimals  $\Delta$ 
```

Here we follow a convention that the variable Δ need not be remembered past the following line.

Stay DRY – don't repeat yourself

If you say something twice (or more) and later have to change it, you have to change it everywhere you said it. Here are some refactoring techniques for removing duplications from your code.

Define variables once – if that

A man with two watches never knows what time it is. On this principle, we avoid redefining variables.

This seems counterintuitive. The point of a variable is that its content can vary. Early programming practice, working with scarce memory, positively encouraged 're-use' of variables, treating them as bins or containers in which to park data.

Experience has taught us great respect for our capacity for confusion. When tracing and debugging, it is a great comfort to know that having found the definition of a variable, there are no other definitions to consider.

The obvious exception is where different possible values are most clearly expressed in control structures, in which case minimise the semantic distance between the different definitions.

```
:if test1
:ElseIf test2 ◊ x←'foo'
:Else ◊ x←'bar'
:EndIf
```

APL.local

Every developer, and every development group, has utility functions uses throughout the code base. Most of these can and should be grouped into topic-specific namespaces, such as the `FilesAndDirs` namespace from the `APLTree` library. Aliasing the namespaces, such as `F←#.FilesAndDirs` allows utility functions to be called in abbreviated form, e.g. `F.Dir` instead of `#.FilesAndDirs.Dir`.

But some functions are so ubiquitous and general it makes better sense to treat them as your local extensions to the language itself. For example the simplified conditional functions `means` and `else` are ‘syntax sweeteners’ that allow you to write

```
:if a=b
    Z←'this'
:else
    Z←'that'
:endif
```

more legibly as `Z←(a=b) means 'this' else 'that'`

Functions `means` and `else` could be defined in say a namespace `#.Utilities` and abbreviated to `U`, permitting

```
Z←(a=b) U.means 'this' U.else 'that'
```

But you might reasonably prefer to omit even the `U.` prefix.

Defining ubiquitous utilities

Here is how to define your `Utilities` namespace in the workspace root so that you can refer to them without prefixes.



Every function or object you include in the root as your ‘local extension’ to the APL language effectively becomes a reserved word in your ‘local’ APL dialect. Be conservative and define functions this way only when you have found them ubiquitous and indispensable!

...

Some utilities you might like to make ubiquitous

Hooray for arrays

You've already discovered how APL lets you write code that is helpfully light on 'ceremony'. For example, you don't have to declare variable types or loop through collections. Here are some more advanced array programming techniques that might give you a further lift.

Functional is funky

Functional style makes your code easier to test, debug and re-use.

Complex data structures

Some ways array programmers commonly use to represent more complex data structures, such as trees, dictionaries and tables.

Passing parameters perfectly

The ghastliness of globals

Nothing is handier when developing your code than keeping bits of information in global variables. They are like the Post-It™ notes or scraps of paper on your real-world desktop. They have no place in your application. Here's why professional programmers keep the global symbol table as empty as possible – and how.

Coding with class

Classes are like micro-workspaces, and a great way of organising your code and data into modules.