Tricks of the Wizards

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- If you don't understand this, you may not get much out of this class:

```
my $x = M->yup(13);
print $x->{V}, "\n";

sub M::yup { my ($p, $v) = @_; bless {V => $v}, $p }
```

What We'll See

- Magic
  - Dark hidden corners of Perl
  - Strange Incantations
- Specifically
  - Globs
  - More globs
  - Tie
  - Source Filters
  - Powerful uses of these things

Prerequisites

You Must Already be Conversant with:

- Packages
- References
- Objects
- Modules

If not, so sorry!

- Gildor says: ‘‘Do not meddle in the affairs of Wizards’’

Warning

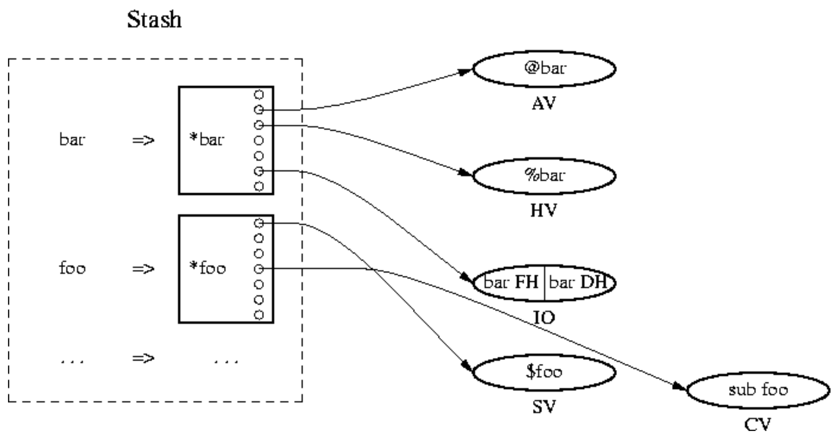
- These techniques are powerful but strange
- They might make your programs hard to understand
- ‘Incantation’ or ‘Idiom’?
- The Mighty Marvel Wizard says: ‘‘With great power comes great responsibility’’
- Everything looks ’obfuscated’ the first time you see it
- No complaints about obfuscation, please

Warning #2

- Many of the techniques we'll see *directly* violate `strict refs` in the grossest and most blatant ways.
- That is not a flaw in the methods.
- `strict refs` is a safety feature.
- If you want to learn to use the Wand of Fireballs, you have to shut off the automatic sprinklers first.
- No complaints about `strict` failures, please.

Principles Of Magic

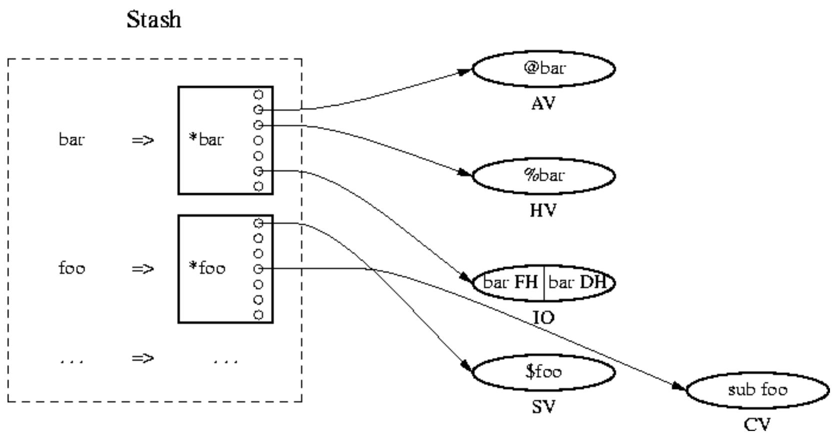
- Much magic is about making things appear to be what they're not
- First we have to understand what makes things appear as they are -- `$foo` for example?
- The Perl Symbol table:



- Several parts:
  - The stash
  - The globs
  - The SVs, AVs, HVs, etc.

The Magic Path to Enlightenment

- How is the value of `$foo` looked up?



- Figure out package name

```
    Parse::RecDescent::foo --> Parse::RecDescent
                 Person::new --> Person
                         foo --> (Whatever is current)
```

- Look in stash for package, locate key `foo`
- Value is a glob. Extract `SCALAR` part of glob.
- Result is a pointer to an SV
- The SV is the value. (`NULL` pointer == `undef`)

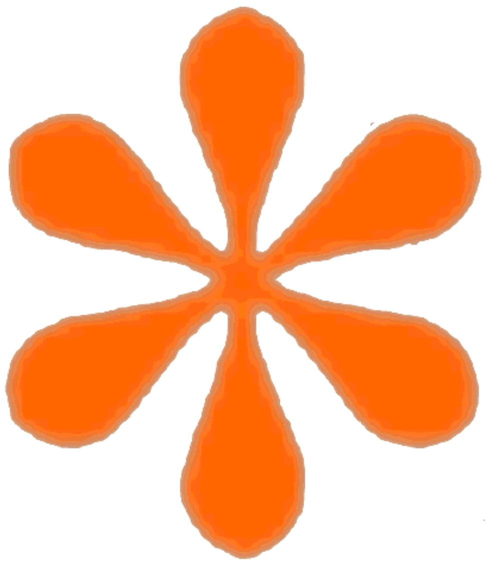
The Magic Path to Enlightenment

- The stash is a hash whose values are globs
- The values are pointers attached to the knobs of the globs
- Follow the knob of the glob in the hash for the stash

- All of these steps are interesting.
- We can benefit by enchanting any of them.
- Globs first.

Making Things Appear to Be What They’re Not

Part I: Globs



Accept no substitutes

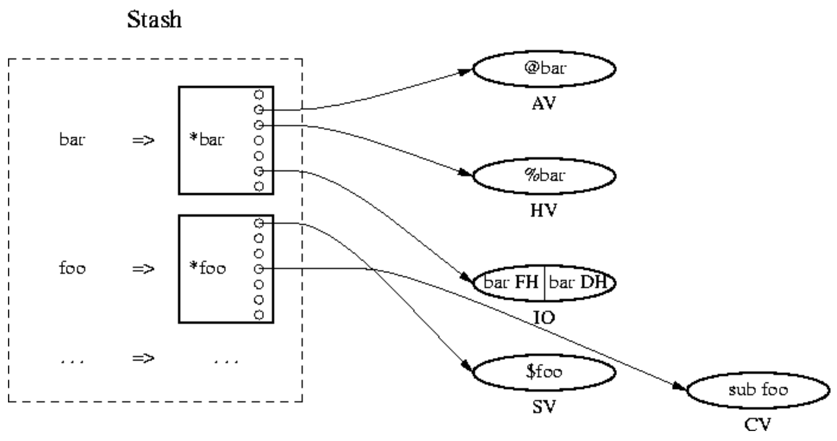
- Despite the resemblance, globs have nothing to do with this:

Globs

- A glob is the glue between the symbol tables and the actual values.
- We're going to spend a lot of time on globs
- A glob has seven parts:
    - `SCALAR`
    - `ARRAY`
    - `HASH`
    - `CODE`
    - `IO`
    - `FORMAT`
    - `GLOB`

Globs

- A glob has seven parts:



Globs

- When perl resolves a variable name, it goes through the glob
- Tinkering with the globs alters the way variables are looked up
- Glob notation in Perl:

```
*foo
```

Operations with Globs

- Most useful:

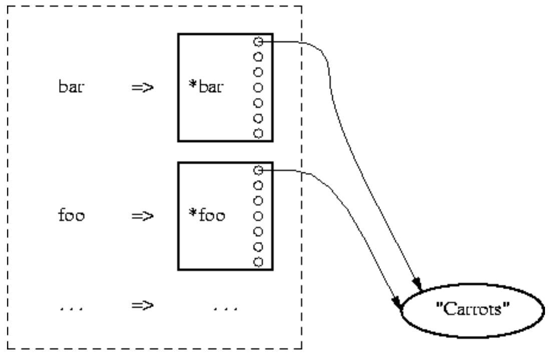
```
    *foo = REFERENCE
```

- The thing referred to is attached to the appropriate glob knob

Operations with Globs

- This performs installation into the symbol table

```
*bar = \$foo;
```



```
*bar = \$foo;
```

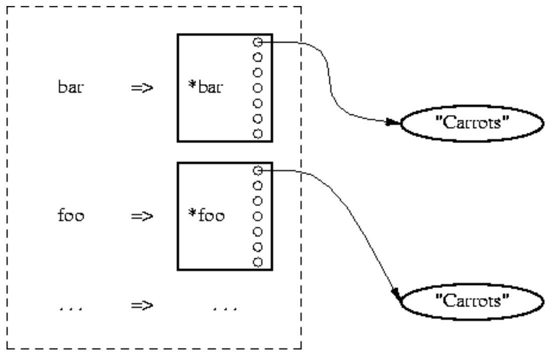
- The glob assignment *aliases* the value

Aliasing

```
*bar = \$foo;
```

- Aliasing is different from assignment:

```
$bar = $foo;
```



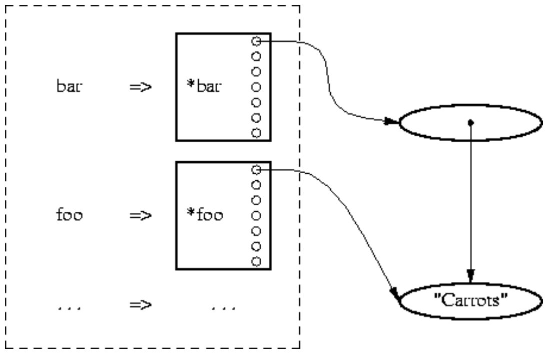
- Assignment *copies* the SV and installs the *copy* into the symbol table

Aliasing

```
*bar = \$foo;
```

- Aliasing is different from assigning a reference:

```
$bar = \$foo;
```



- `\$foo` constructs a *new SV* with a *reference* value
- The *reference* is installed into the symbol table

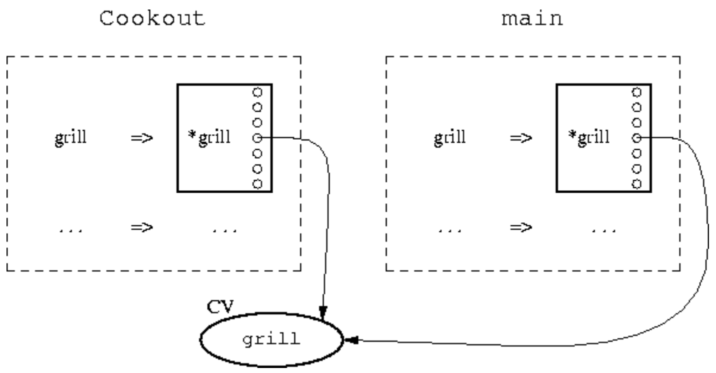
Exportation

```
package Cookout;

sub import {
  my $caller = caller;
 *{$caller . '::grill'} = \&grill;
}

sub grill {
  ...
}
```

- This module *exports* the function `grill` into the calling package:

```
use Cookout;       # Calls Cookout->import()
grill('kebabs');   # Calls Cookout::grill('kebabs')
```

- `$caller . '::grill'` turns into `main::grill`



- Now you know how the `Exporter` works

Exportation

- Here’s a slightly more full-featured exporter.

```
package Rings;
use Carp;

%exports = map {$_ => 1} qw(Narya Nenya Vilya);

sub import {
  my $caller = caller;
  my $package = shift;
  for my $name (@_) {
    unless ($exports{$name}) {
      croak("Module $package does not export &$name; aborting");
    }
    *{$caller . '::' . $name} = \&{'Rings::' . $name};
  }
}

sub Narya { ... }
sub Nenya { ... }
sub Vilya { ... }
```

- In the main program, calls like this:

```
use Rings qw(Narya Nenya Fred);
```

- Turn into this:

```
Rings->import(qw(Narya Nenya Fred));
```

`croak`

- Consider: `main.pl`

```
#!/usr/bin/perl
use Rings qw(Narya Nenya Fred);
```

- And `Rings.pm`

```
...
die "Module $package does not export &$name; aborting";
...
```

- This yields

```
... does not export &Fred; aborting at line 379 of Rings.pm.
```

- Not very useful
- With `croak` instead of `die`

```
... does not export &Fred; aborting at line 2 of main.pl.
```

- Similarly `carp` instead of `warn`

Forced Importing / Aliasing

- Module `VeryLongName` contains function `SomeFunction`.
- Instead of calling `VeryLongName::SomeFunction` many times:

```
{ local *F = \&VeryLongName::SomeFunction;

  F(...);
}
```

- A more realistic example:

```
*ERR = \$DBI::errstr;
```

Forced Importing / Aliasing

- Another real example: `Module` has a function you want, but the name is wrong:

```
use Module 'function';
```

- Perhaps this is no good because it overlaps some other `function` that you need
- For example:

```
sub get { ... }       # Clobbered by LWP::Simple::get
use LWP::Simple;      # Ouch --- exports 'get' by default
```

- Do this instead:

```
use LWP::Simple ();   # Load, but don't import anything
BEGIN { *webget = \&LWP::Simple::get }
```

- `use Module ()` is a weird special case
- It loads `Module` but does not call `import` at all

(No) Globs in Perl 6

- Everyone seems to know that Perl 6 won't have globs
    - (Even people who don't know what globs are)
- In Perl 5, globs are essential to exporting
    - How will exportation be handled in Perl 6?
- Exportation is an aliasing operation
- Perl 6 has an explicit aliasing operator `:=`

```
$new := $old;
@new := @old;
%new := %old;

@new := $oldref;
%new := $oldref;
```

- These will work even if `new` is a lexical variable

(No) Globs in Perl 6

- For exportation to another package one will use:

```
%Cookout::{'&grill'} := \&grill;
```

- Stashes in Perl 6 are still hashes
- They have names that end in `::`
- The key `&grill` in a stash is associated with the function object
- The Exporter itself will do something like

```
my $calling_package = caller().package;
my %Exporter::To:: := %{$calling_package _ '::'}
...
%Exporter::To::{$name} := %Exporter::From::{$name};
```

Passing Filehandles

- In The Beginning, filehandles weren't first-class values
- Consider code like this:

```
open FH, ...;
print FH ...;
$z = <FH>;
close FH;
```

- Here `FH` is actually a *literal string* (a 'bareword')
- Almost as if you had written something like this:

```
open "FH", ...;
print "FH" ...;
$z = <"FH">;
close "FH";
```

- All Perl's I/O functions expect to get strings
  - They then resolve the string to a glob in the usual way
  - Then they extract the filehandle part of the glob

Passing Filehandles

- This method for filehandles causes some problems

```
open FH, ...;
$data = read_block(FH);

package My::IO;

sub read_block {
  my $fh = shift;
  my $buf;
  read $fh, $buf, $BLOCKSIZE;
  $buf;
}
```

- Here the `read` function is given the string `FH`
  - But `FH` means `My::IO::FH`, not `main::FH`
  - Function doesn't work

Passing Filehandles

```
$data = read_block(FH);        # Doesn’t work

package My::IO;

sub read_block {
  my $fh = shift;
  my $buf;
  read $fh, $buf, $BLOCKSIZE;
  $buf;
}
```

- Solution 1:

```
$data = read_block(main::FH);
```

- Solution 2:

```
$data = read_block(\*FH);
```

- Perl’s I/O functions all will glob references
  - They then access the glob through the reference instead of through the stash

Passing Filehandles

- Similarly:

```
open my $fh, ...;
```

- This now creates a new filehandle and stores it in `$fh`
- What is actually created?

```
print "$fh\n";
GLOB(0x80f7b0c)
```

- A glob reference
- It’s a glob that’s not part of the symbol table
  - There are no aliasing effects on assignment
- In Perl 6, `open` will simply return a filehandle object:

```
my $fh = open $filepath : mode=>’rw’
```

- It will probably stringify as something like `IO(0x436c1d)`

Globjects

- You’re probably familiar with using a blessed hash as an object
- Hash elements are like C++ class members
- Many people suggest using an array for space and time efficiency
  - See Greg Bacon’s TPJ article
  - This trick was codified in 5.005’s *pseudohash* feature
    - Which was subsequently removed

Globjects

- Base object on array? Or hash?
- There are tradeoffs here
- What if you need both? Use a glob!
- A glob contains a hash *and* an array
- And also a filehandle

Globjects

- The biggest win is using the filehandle part
- Perl accepts a glob reference anywhere it normally expects a filehandle
- If your object is a blessed glob reference, people can use it like a filehandle
- Let’s write an object that looks like a regular filehandle
  - But it supports a `flush` method that flushes any buffered data

Globjects

```
package IO::Flushable;
sub new {
  my ($package, $mode, $filename) = @_;
  open my $fh, $mode, $filename or return;
  bless $fh => $package;
}
```

- People can use this object just like a filehandle:

```
my $fh = IO::flushable->new(">", "logfile") or die ...;
print $fh "Blah blah blah\n";
syswrite $fh, $logentry;
close $fh;
```

- It also closes automatically when it is destroyed.

Globjects

- I promised a `flush` operation
- `$fh->flush()` will flush the handle

```
        sub flush {
          my ($self) = @_;                # $self is a GLOB reference
          my $ofh = select $self;
          my $rc;
          { local $| = 1;
            $rc = print $self "";
          }
          select $ofh;
          return $rc;
        }
```

Globjects

- Here's a more interesting example
- It's like a regular filehandle
  - But it has a `remember` operation that remembers the current file position
  - And a `gobackto` operation that goes back to a saved position
- Changing positions is accomplished with Perl's `seek` and `tell` functions

```
        my $pos = tell FH;
        seek FH, $pos, 0;
```

Globjects

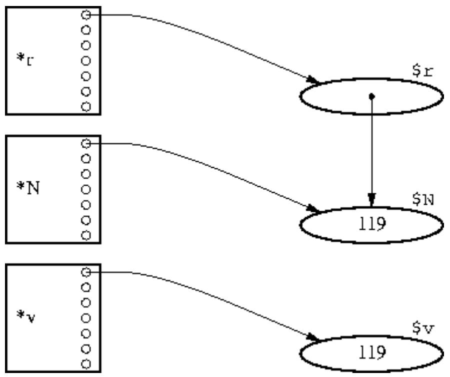
- The constructor is similar to the previous example:

```
package IO::Remembers;
sub new {
  my ($package, $filename) = @_;
  open my $fh, $filename or return;
  bless $fh => $package;
}
```

- Once again it can be used like a regular filehandle:

```
my $fh = IO::Remembers->new('input');
my $line = <$fh>;
read $fh, $bytes, 1024;
close $fh;
```

Globjects



- Before we see `remember` and `gobackto`, here's some syntax
- You can use a glob as if it were a reference to any sort of thing.
- For example:

```
$N = 119;
$v = ${*N};
$r = \${*N};
```

- `$v` now contains 119
- `$r` now refers to `$N` so that `$$r` is 119.
- In particular, if `*g` is a glob, `%*g` is its hash
  - `*g->{key}` looks up `key` in the hash
- If `$gr` is a globref, `*$gr` is the glob
  - `%*$gr` is the glob's hash
  - `*$gr->{key}` looks up `key` in the hash

Globjects

- `$fh->remember('hippo')` will save the current position under the key `hippo`.

```
sub remember {
  my ($self, $key) = @_; # $self is a GLOB reference
  *$self->{$key} = tell $self;
}
```

- `$fh->gobackto('hippo')` will return to the saved position.

```
sub gobackto {
  my ($self, $key) = @_;
  seek $self, *$self->{$key}, 0;
}
```

- Future reads from the ‘filehandle’ will continue from the old position

Globjects

- In Perl 6, this will be more straightforward
- Filehandles will just be objects from class `IO`
  - Built-in functions like `print` and `<>` will be method calls
- So just subclass `IO` and add the methods you want

Wrappers

- Suppose we'd like to trace execution of the functions in a package
- To do that, we'll replace each function with a 'wrapper'
    - The wrapper will announce that the function is being called
    - Then call the real function
- Basic idea:

```
my $real_func = \&*$func_name;
*$func_name = sub {
  print "$func_name(@_)\n";
  $real_func->(@_);
};
```

Wrappers

```
package Trace;

sub import {
  my $caller = caller;
  my @functions = @_ ? @_ : all_functions($caller);
  for my $func_name (@functions) {
    my $real_func = \&*$func_name;
    *{$caller . "::$func_name"} = sub {
      print "$func_name(@_)\n";
      $real_func->(@_);
    };
  }
}
```

Stash Walking

```
my @functions = @_ ? @_ : all_functions($caller);
```

- How can we get a list of all the functions in a package?
- We'll examine the stash directly
- It's just a hash
- The stash for package `RINGS` is available as `%RINGS::`
    - Keys are names, values are globs

```
sub all_functions {
  my $p = shift;
  my $h = \%{$p . "::"};
  my @result;
  while (my ($name, $glob) = each %$h) {
    if (defined &$glob) {
      push @result, $name;
    }
  }
  @result;
}
```

Miscellaneous Applications of Globs

Read-Only Constants

```
*PI = \3;
```

- Now `$PI` is 3:

```
$circum = 2 * $PI * $r;
```

- But attempts to assign to `$PI` fail:

```
$PI = 4;

Modification of a read-only value attempted at ...
```

Miscellaneous Applications of Globs

Read-Only Constants, Continued

```
sub PI () { 3 }
```

- Now you can use `PI` and get 3:

```
$circum = 2 * PI * $r;
```

- `PI` is still read-only:

```
PI = 3;
```

```
Can’t modify constant item in scalar assignment at ...
```

- `()` enables special function-call syntax
- This incantation also enables *inlining* optimization

Read-Only Constants Continued

```
use constant PI        => 3,
             e         => 2.71828182845904523536,
             emptylist => [];
```

- `constant.pm` uses a combination of the read-only techniques and exportation:

```
package constant;

sub import {
  my $caller = caller;
  my $package = shift;
  while ($name = shift) {
    my $value = shift;
    *{$caller . '::' . $name} = sub () { $value };
  }
}
```

A Templating System

- This is a pretty big spell.
- You have a hashful of variables, `%VARS`
- You want to `eval` some code, and you want the environment for the `eval` to be the variables defined by the *hash*.
- For example, many templating modules need to do this

```
my %VARS = ( cust_id => 666,
             items   => ['fish', 'dog', 'carrot'];
             amount  => 142857.33,
           );

my $template = <<'EOM'; # Or read it from a file

  $name = db_lookup('NAME', $cust_id);
  $title = db_lookup('TITLE', $cust_id);
  $n = @items;
  $items = $n == 1 ? "item" : "$n_items items";

  return "Dear $title $name,
     You still owe me \$$amount for the following $items:
        @items\n";
EOM
my $result = my_eval($template, \%VARS);

# Result:
# Dear Mr. Gates,
#   You still owe me $142857.33 for the following 3 items:
#      fish dog carrot
```

- Note: `$cust_id`, `@items`, and `$amount` implicitly defined by the hash
- Note: `$name`, `$title`, `$n`, and `$items_list` don't 'leak out'

A Templating System

Three Parts to Our Strategy

1. Make up a new package
2. Install the hash variables into the new package
3. Do the `eval` in the new package

A Templating System

Make Up a New Package

- Straightforward:

```
my $fake_pack;
BEGIN { $fake_pack = 'Fake00'}
sub new_package {
  return "HashEval::" . $fake_pack++;
}
```

- `Symbol::gensym` already does something like this
- After we're done with a package, we can destroy it by using the `Symbol::delete_package` function

A Templating System

Install Hash Variables Into the New Package

```
sub package_install {
  my ($h, $p) = @_;
  my $n;
  while ($n = each %$h) {
    my $v = $h->{$n};
    *{$p . '::' . $n} = (ref $v ? $v : \$v);
  }
}
```

- Scalar context `each` just returns the keys one at a time

A Templating System

Do the `eval` in the New Package

```
sub my_eval {
  my ($program, $hash) = @_;
  my $pack = new_package();
  package_install($hash => $pack);
  my $result = eval "package $pack; $program";
  return $result;
}
```

A Templating System

Caveats

- The `eval`'ed code is not actually *confined* to the new package:

```
$/ = 'e';    # Sucker!

$Security::ENABLED = 0;    # Double sucker!
```

- `eval` is still `eval`

```
system("rm -rf /");
```

- To prevent these, you need to `use Safe`.
- The hash-into-new-package strategy is still valuable in conjunction with `Safe`.

```
my $result = Safe->new->reval($program);
```

- `Text::Template` is an extended example of this.

Making Things Appear to Be What They're Not

Part II: Ties

Ties

- A *tied* variable has its accesses mediated by a Perl object.
- For example, if the scalar `$s` is *tied* to the object `$o`, then

```
print $s;                  print $o->FETCH();
$s = 119;                  $o->STORE(119);
```

Ties: Trivial (Annoying) Example

Make Something Look Strange

- Tied variables are the ultimate in things that appear what they're not:

```
sub STORE {
  my ($self, $val) = @_;
  # Return value is ignored
}

sub FETCH {
  return "You are not cleared for access to that information.";
}
```

- Now what?

```
$cia = "I'm a happy little bunny wabbit";
$cia =~ tr/A-Z/a-z/;
$cia .= "foo";

print $cia;
```

```
You are not cleared for access to that informa
```

How to Tie

- Basic syntax:

```
tie $VAR => PACKAGE, arguments;
tie @VAR => PACKAGE, arguments;
tie %VAR => PACKAGE, arguments;
tie *VAR => PACKAGE, arguments;
```

- Turn into

```
PACKAGE->TIESCALAR(arguments);
PACKAGE->TIEARRAY(arguments);
PACKAGE->TIEHASH(arguments);
PACKAGE->TIEHANDLE(arguments);
```

- The `TIEXXX` function must construct and return an object to be associated

Tied Scalar Example

```
use Sequence;
tie $IDS => Sequence, 17;          # $IDS is special now

$id = $IDS;                        # $id is now 17
$another = $IDS;                   # $another is now 18
print $IDS, "\n";                  # Prints 19
push @ids, $IDS;                   # Pushes 20

$IDS = 17;                         # Reset to 17
```

Tied Scalar Example

```
package Sequence;

sub TIESCALAR {
  my ($package, $start) = @_;
  $start = 1 unless defined $start;
  my $object = {VALUE => $start};
  bless $object => $package;
}

sub FETCH {
  my ($self) = @_;
  $self->{VALUE}++;
}

sub STORE {
  my ($self, $newvalue) = @_;
  $self->{VALUE} = $newvalue;
}
```

Tied Hash Example

A hash with case-insensitive keys

```
use Insensitive;
tie %hash => Insensitive;

$hash{SomeKey} = 'somevalue';
$hash{'John MacDonald'} = 'Author';

print $hash{somekey}, "\n";            # Prints 'somevalue'
print $hash{'John Macdonald'}, "\n";    # Prints 'Author'

$hash{SOMEKEY} = 57;
print $hash{SomeKey}, "\n";            # Prints 57
```

Tied Hash Example

```
package Insensitive;

sub TIEHASH {
  my ($package) = @_;
  my $object = {};
  bless $object => $package;
}

sub STORE {
  my ($self, $key, $value) = @_;
  $self->{lc $key} = $value;
}

sub FETCH {
  my ($self, $key) = @_;
  $self->{lc $key};
}
```

CGI.pm

- `CGI.pm` provides a `->param()` method for getting the submitted web form data
- For compatibility with older packages, it will also set up an `%in` hash
- `%in` is tied to call `->param()` behind the scenes

```
sub FETCH {
    return $_[0] if $_[1] eq 'CGI';
    return undef unless defined $_[0]->param($_[1]);
    return join("\0",$_[0]->param($_[1]));
}
```

- Other methods similarly

Exporting a Tied Variable

- You can `tie` any scalar, array, or hash variable.
- It could be global or lexical
- You can export it also
- You can use this to write a module that places a magical variable into the package that uses it.
- Normally, `use Package` imports some functions in the program that says it
- But you can make `use Package` mean to import some magical variables instead

Config.pm

- Perl’s standard `Config` module supplies a magical `%Config` hash
  - It appears to be full of information about Perl’s configuration

```
use Config;

print "osname = $Config{osname}\n";
print "install module manuals into  = $Config{installman3dir}\n";

   osname = linux
   install module manuals into  = /usr/local/man/man3
```

- Actually `%Config` is a tied hash

```
package Config;
...
@EXPORT = qw(%Config);
...

sub import {
  ...

  *{"$callpkg\::Config"} = \%Config;
}

...

tie %Config, 'Config';

1;
```

- `"$callpkg\::Config"` is equivalent to `$callpkg . "::Config"`
  - `"$callpkg::Config"` means something else

Config.pm

- `Config.pm` contains most of the configuration information as a giant string
- The string is *not* parsed when you load the module
- Instead, the `FETCH` method searches it for the configuration variable you asked for
- Then it caches the result
- `FETCH` also generates some of the configuration information dynamically
- `%Config` is read-only:

```
sub STORE  { die "\%Config::Config is read-only\n" }
```

Magical Exporter Variable

- This nifty trick was invented by Andrew Pimlott
- Beginners want to say this:

```
$salary = 43_000;
print "After your raise, you will make $salary*1.06.\n";
```

- But it doesn’t work:

```
 After your raise, you will make 43000*1.06.
```

- Because, of course, expressions aren’t evalauted inside of strings.
- ...or are they?

```
@s = (1, 4, 9, 16, 25, 36);
print "$s[(2+7-1*3)/2]\n";        # Prints 16
```

Exporting a Magical Variable

```
package Eval;

sub import {
  my ($package, $name) = @_;
  $name = ’Eval’ unless defined $name;
  my %magical_hash;
  tie %magical_hash => Eval;
  my $caller = caller;

  *{$caller . ’::’ . $name} = \%magical_hash;
}
```

- There’s that magic glob again.

```
sub TIEHASH {
  my $self = \’dummy’;
  bless $self => ’Eval’;
}
```

- `use Eval` now calls `Eval::import`
- `import` creates and ties a hash, which it exports back to the caller
- When the caller examines the data in the hash, `Eval::FETCH` is called

Exporting a Magical Variable

- Here's `Eval::FETCH`

```
sub FETCH {
 my ($self, $key) = @_;
  $key;                        # Do NOTHING!
}
```

- What was *that* all about?

```
use Eval;

$salary = 43_000;
print "After your raise, you will make $Eval{$salary*1.06}.\n";
```

```
   After your raise, you will make 45580.
```

- If you don't like the syntax, you can change it a little:

```
use Eval => ':';

$salary = 43_000;
print "After your raise, you will make $:{$salary*1.06}.\n";
```

```
   After your raise, you will make 45580.
```

Magical Exporter Variable

- Magic hash is not limited to evaluation:

```
package Format_Money;

sub FETCH {
  my ($dummy, $amount) = @_;
  my ($dollars, $cents) = split /\./, sprintf("%.2f", $amount);
  1 while $dollars =~ s/^([-+]?\d+)(\d{3})/$1,$2/;     # FAQ
  "\$$dollars.$cents";
}
```

- Now:

```
use Format_Money;

$salary = 43_000;
print "After your raise, you will make $Money{$salary*1.06}.\n";
```

```
   After your raise, you will make $45,580.00
```

- Also use for automatic URL character escaping (for example)
- Also see `Interpolation` module

Tied Arrays

- It’s easy to make an array that mirrors the contents of a file

```
tie @FILE, 'MirrorFile', $filename or die ...;
```

- Then

```
print $FILE[13];      # Print line 13

for (@FILE) {
  if (/something/) { ... }
}
```

Tied Arrays

```
package MirrorFile;

sub TIEARRAY {
  my ($package, $filename) = @_;
  open my $fh, "<", $filename or return;
  my $self = { FH => $fh, FILE => $filename, CACHE => [] };
  bless $self => $package;
}

sub FETCH {
  my ($self, $lineno) = @_;
  return $self->{CACHE}[$lineno]
    if defined $self->{CACHE}[$lineno];

  my $fh = $self->{FH};
  while (<$fh>) {
    push @{$self->{CACHE}}, $_;
    return $_ if $#{$self->{CACHE}} == $lineno;
  }
  return;
}

sub FETCHSIZE {
  my ($self) = @_;
  my $fh = $self->{FH};
  push @{$self->{CACHE}}, <$fh>;
  scalar @{$self->{CACHE}};
}
```

- Supporting `STORE` is quite difficult
  - See `Tie::File` for many details

Tied Filehandles

- To tie a handle, tie the glob in which it resides:

```
tie *FH => 'Package', ...;
```

- Tied handle objects must support several methods:

```
CLOSE
GETC
PRINT
PRINTF
READ         (for 'read')
READLINE     (for '<>')
WRITE        (for 'syswrite')
```

Tied Filehandles

- For example, suppose you'd like to trap all `STDOUT` output in a file
- But also send it to `STDOUT` as usual

```
package TeeSTDOUT;

sub import {
  my ($package, @outfiles) = @_;
  open REAL_STDOUT, ">&STDOUT" or die ...;
  my @handles;
  for my $outfile (@outfiles) {
    open my $fh, ">", $outfile or die ...;
    push @handles, $fh;
  }
  tie *STDOUT => 'TeeSTDOUT', \@handles;
}

sub TIEHANDLE {
  my ($package, $fhs) = @_;
  bless $fhs => $package;
}

sub PRINT {
  my ($fhs, $string) = @_;
  for my $outhandle (@$fhs, \*REAL_STDOUT) {
    print $outhandle $string;
  }
}
```

Tied Filehandles

- Suppose you don’t like the `opendir`/`readdir` interface to directories
- Why not a regular filehandle?
- Then you could do:

```
use Dir;
my $dh = Dir->open(".") or die ...;
while (<$dh>) {
  # Do something with the filename in $_
}
close $dh;
```

- We’ll do this by tying the handle in `$dh`, which will allow us to overload the `<...>` operator on it

Tied Filehandles

```
package Dir;

sub open {
  my ($package, $dir) = @_;
  opendir my $dh ,$dir or return;
  local *FH;
  tie *FH => 'Dir', $dh, $dir;
  return \*FH;
}

sub TIEHANDLE {
  my ($class, $dirhandle, $dirname) = @_;
  my $self = { DH => $dirhandle, NAME => $dirname };
  bless $self => $class;
}

sub READLINE {
  my ($self) = @_;
  readdir($self->{DH});
}
```

Tied Filehandles

```
sub READLINE {
  my ($self) = @_;
  readdir($self->{DH});
}
```

- Or perhaps you would prefer that `<$dh>` returns an object representing the directory entry:

```
sub READLINE {
  my ($self) = @_;
  my $file = readdir($self->{DH});
  my $fullname = "$self->{DIRNAME}/$file";
  my @statinfo = stat($fullname);
  return unless @statinfo;
  return Dir::Statinfo->new(FULLNAME => $fullname,
                            BASENAME => $file,
                            STATINFO => \@statinfo);
}
```

- And then use it like this:

```
while (<$dh>) {
  print $_->fullname, " is a ", $_->filetype;

  print " containing ", $_->size, " bytes"
    if $_->filetype eq 'plain file';

  print " linking to ", $_->readlink
    if $_->filetype eq 'symbolic link';

  print "\n";
}
```

Missing `tie` Methods

- If you assign to a tied variable and you don't have a `STORE` method defined, you'll get a fatal error.
- The standard `Tie::StdScalar`, `Tie::StdArray`, and `Tie::StdHash` classes provide reasonable defaults.
- But for simple behavior, an easy thing to do is

```
sub unimplemented { }
```

- or

```
# Load 'Carp' when needed
sub forbidden {
  require Carp;
  Carp::croak("Operation not permitted on tied hash");
}

for $name (qw(STORE DELETE CLEAR FIRSTKEY NEXTKEY)) {
  *{$name} = \&forbidden;
}
```

- There's that magic glob again.

The Mother of All Bizarre `tie` Tricks

- Some badly-designed library subroutine reads from or writes to a certain variable
- You wish it
  - read from a file
  - wrote to a database
  - called a callback function
  - etc. etc. etc.

instead.

- Solution: Tie the variable.
  - Now it *does* call a callback function instead

The Mother of All Bizarre `tie` Tricks

- Best application: Tied filehandle.

```
do_something(...);
```

- And then to your dismay, `do_domething` prints a lot of blather on the `STDOUT`
  - And you cannot get it to shut up
  - Moreover, you want the program to examine the error log for diagnostics
- So tie `STDOUT`:

```
{ my $output;
  tie *STDOUT => 'TrapOutput', \$output;
  do_something();            # Blessed silence
  untie *STDOUT;
  # Now examine $output
}

sub TrapOutput::TIEHANDLE {
  my ($class, $var) = @_;
  bless $var, $class;
}

sub TrapOutput::PRINT {
  my ($self, $string) = @_;
  $$self .= $string;
}
```

- Final remark: `ArrayHashMonster` may amaze and delight you

Making Things Appear to Be What They're Not

Part III: Filters

What's a Filter?

- A filter gets the Perl source code before the parser does
- It can transform the code any way it wants to
- Then it hands the result to Perl
- For example:
  - The source code file might be compressed
    - A filter can uncompress it before Perl sees it
  - The source code file might be encrypted
    - A filter can decrypt it before Perl sees it
  - The source code file might contain non-Perl features like macros
    - A filter can translate these to Perl before Perl sees it
- Filtering is described in the beautifully-written `perlfilter` man page
  - Much of this work was done by Paul Marquess

`Filter::Simple`

- The easy way to do filtering is with `Filter::Simple`
- We'll build a module that understands rot13-scrambled source code
    - Rot13:

```
abcdefghijklm nopqrstuvwxyz ABCDEFGHIJKLM NOPQRSTUVWXYZ
nopqrstuvwxyz abcdefghijklm NOPQRSTUVWXYZ ABCDEFGHIJKLM
```

- Our test program looks like this:

```
use Rot13;

zl $f = "Uryyb, jbeyq\a";
$| = 1;
sbe (0 .. yratgu($f)) {
  cevag fhofge($f, $_, 1);
  fyrrc 1 vs enaq() < .5;
}

no Rot13;

print "All done!\n";
```

- And in fact this works as written, and produces the output:

```
Hello, world
All done!
```

`Filter::Simple`

- The magic, of course, is in the `Rot13` module:

```
package Rot13;
use Filter::Simple;

FILTER {
  tr/A-Za-z/N-ZA-Mn-za-m/;
};

1;
```

- It really couldn't be any simpler

Filter::Util::Call

- The filter interface is very complicated
- `Filter::Simple` is based on `Filter::Util::Call`
- Which in turn was invented as a simplified interface
- That's why software is great

Filter::Util::Call

- Here's a skeleton usage:

```
package Rot13 ;

use Filter::Util::Call ;

sub import
{
    my($type, @arguments) = @_ ;
    my $result = "";

    filter_add(
        sub
        {
            my $status = filter_read() ;
            if ($status >= 0) {
              tr/A-Za-z/N-ZA-Mn-za-m/;
            }
            return $status;
        } )
}

1 ;
```

- A filtering module should provide an `import` which calls `filter_add`
- `filter_add` sets up the filter, which calls `filter_read`
- `filter_read` places a line of code into `$_`
- The filter modifies `$_` and returns

Filter::Util::Call

- The filter on the previous slide does not honor `no Rot13`
- And how could it?
  - The filter itself gets the `no Rot13` before the compiler does!
- However, it's easy to make it honor `ab Ebg13;` directives:

```
        sub unimport {
         warn "Unimport...\n";
         filter_del();
        }
```

- Now the filter gets the `ab Ebg13;` line
  - Rot13s it to `no Rot13;`
  - Returns it to the compiler
  - The compiler compiles the line and calls `Rot13::unimport`
  - `unimport` deletes the filter
  - The parsing and compilation process continues as usual

Filter::Util::Call

- The previous version supports `ab Ebg13;` but not `no Rot13;`
- For that we have to be a little more devious:

```
        ...
        if ($status >= 0) {
          if (/^\s*   no  \s+  Rot13  \s*   ; # "no Rot13;"
                \s* (?: #.* )?  $            # Optional WS or comment
              /x) {
            return $status;
          }
          tr/A-Za-z/N-ZA-Mn-za-m/;
        }
        ...
```

- We examine the line for `no Rot13;` *before* we give it to the compiler
- If so, we return the line *without* rot13ing it
- We could also have called `filter_del()` directly
- `Filter::Simple` does this automatically

`Filter::Util::Call`

```
...
if ($status >= 0) {
  if (/^\s*  no  \s+  Rot13  \s*  ; # "no Rot13;"
        \s* (?: #.* )?  $           # Optional WS or comment
      /x) {
    return $status;
  }
  tr/A-Za-z/N-ZA-Mn-za-m/;
}
...
```

- Note that this won't pick up a line like this one:

```
no Rot13;   print "I like pie.\n";
```

- But it will pick this up:

```
$z = qq{
no Rot13;
};
```

- You just have to hope that nothing like that comes along
- In general, source filtering is based on hopes like this one
- You can write a filter that works most of the time
- But faced with sufficiently weird code, it will break

"Only `perl` can parse Perl"

- People are fond of saying this
- If you want to know what Perl will think of some program, you must ask `perl` itself
- No regex or other simple process will always produce the right answer
- This is because to parse Perl, you also have to be able to *interpret* Perl
- Bizarre but typical example:

```
$t = time / 3;          # Is this a comment? /;

$s =  sin / 3;          # Is this a comment? /;
```

- Now what about this?

```
$u = blub / 3;          # Is this a comment? /;
```

- You need to know if `blub` is like `time` or like `sin`

"Only `perl` can parse Perl"

```
$u = blub / 3;          # Is this a comment? /;
```

- Where did `blub` come from?

```
package Blub;
use Astro::MoonPhase;

sub import {
  my $caller = caller;
  my ($phase) = phase(time());
  if (0.4 < $phase && $phase < 0.6) {
    *{$caller . "::blub"} = sub () { 1 };
  } else {
    *{$caller . "::blub"} = sub ($) { $_[0] };
  }
}
```

- This program parses differently when the moon is full
  - So to fully parse all Perl programs, you must be able to determine the phase of the moon
- And that's why only `perl` can parse Perl
- Nevertheless, filters can do reasonably well in practice

Function Tracing Again

- `Filter::Simple` can help out with the parsing a little
- Suppose we'd like to instrument each function to announce itself when it's called
- It is sufficient to have each function call 'trace':

```
sub trace {
  ($package, $file, $line, $subr) = caller;
  my $depth = 0;
  1 while defined caller(++$depth);
  my $indent = "  " x ($depth - 2);
  local $" = ', ';
  print "$package\::$subr(@_)\n";
}
```

- Our source filter will find this:

```
sub something {
  ...
```

- And replace it with this:

```
sub something {
  &Trace::trace;
  ...
```

Function Tracing

```
package Trace;
use Filter::Simple;

sub trace { ... }

FILTER_ONLY code => sub {
  s{^(\s* sub \s+ [a-zA-Z_]\w* \s* \{)}
   {$1 &Trace::trace; }xmg;
};
```

- `FILTER_ONLY code` will *not* modify this:

```
$z = "
sub z {
 Oh no!
}
";
```

- The code that's passed to the filter actually has

```
$z = \034\000\000\000\001\034;
```

- `Filter::Simple` puts this back the way it was afterwards

Internationalization

- Let's convert a program to run in other languages

```
print "Hello there!\n";
print "Should I erase all your files (yes/no)?  ";
chomp(my $response = <>);
if ($response eq 'yes') {
  system("rm -rf $ENV{HOME}");
}
```

- The program shouldn't actually say `Hello there!`
- Instead, it should consult a database of texts
- In Mexico, the database will contain `¡Buenos dias!` instead

Internationalization

```
package Translate;
use Filter::Simple;

my %lexicon =
( 'Hello there!\n' => "¡Buenos Dias!\n",
  'Should I erase all your files (yes/no)?  '
        => '¿Debo borrar todos sus archivos (si/no)?  '
  'yes' => 'si',
);

FILTER_ONLY string => sub {
  unless (exists $lexicon{$_}) {
    warn qq{No translation for "$_"\n};
    $lexicon{$_} = $_;
  }
  $_ = $lexicon{$_};
};
```

- Or more likely the `%lexicon` will be tied to a disk database

`Perl6::Variables`

- The Perl 6 variable syntax is a little different
- Beginners always want element 3 of `@array` to be `@array[3]`
- In Perl 6, it is.

```
Perl 5          Perl 6
---------------------------
$s              $s
$a[$n]          @a[$n]
$h{$k}          %h{$k}
$s->[$n]        $s[$n]
$s->{$k}        $s{$k}
$s->(@a)        $s(@a)
```

- We'll build a filter that translates Perl 6 syntax to Perl 5's

Perl6::Variables

```
package Perl6::Variables;
use Regexp::Common;
use Filter::Simple;

FILTER_ONLY code => \&translate,
            string => \&translate_string,
;
```

- `Filter::Simple` will call `translate_string` on each string in the program
- It’ll also call `translate` on the entire code, but with the strings ’blanked out’
  - That way we needn’t worry about applying code transformations to strings
- Filtering strings is similar to filtering code
  - Except we have to worry about backslash escapes

```
Perl 6          Perl 5
---------------------------
  @array[3]       $array[3]
 \@array[3]      \$array[3]"
 "@array[3]"     "$array[3]"
"\@array[3]"    "\@array[3]"
```

- So `translate_string` will pass a flag to `translate` to tell it to handle backslashes

```
sub translate_string { translate_code(1) }
```

Perl6::Variables

- The rest of it is mostly an exercise in regexology

```
sub translate_code {
  my $doing_a_string = shift;
  my $result = "";

  while (1) {
    if ($doing_a_string) {  # Handle backslashes
      /\G((?:\\\\)+)(?!=\\)/gc and $result .= $1, next;
      /\G((?:\\\\)+)\\./sgc and $result .= $1, next;
    }

    if (/\G([\$\@\%]) ($name) ($P) /sgcx) {
      my $arrow = "";
      my ($sigil, $var, $subs) = ($1, $2, $3);
      $arrow = "->" if $sigil eq ’$’;
      $result .= join "", ’$’, $var, $arrow, $subs;
      next;
    }
    /\G([\w\s]+)/gc and $result .= $1, next;
    /\G(.)/sgc and $result .= $1, next;
    last;
  }

  $_ = $result;
}
```

- The real `Perl6::Variables` is just a more extensive exercise in regexology

Making Things Appear to Be What They’re Not

Part IV: Autoloading

What is Autoloading?

- What happens when you call a function that isn’t there?
- Perl looks for a function named `AUTOLOAD` in the same package
- If it finds it, it calls it
- `AUTOLOAD` is a catchall for undefined functions
- Similarly for methods
  - `$o->METH` searches the inheritance tree for `METH`
  - If it’s not there, the inheritance tree is searched again for `AUTOLOAD`

Simple `AUTOLOAD` Example

```
@funcs = qw(red yellow blue);

sub red    { ... }
sub yellow { ... }
sub blue   { ... }

sub AUTOLOAD {
   die "Function $AUTOLOAD unknown; try [@funcs]\n";
}
```

- Now if you do

```
green(...);
```

- You get this:

```
Function main::green unknown; try [red yellow blue]
```

- The name of the would-be function is placed in `$AUTOLOAD`

Simple `AUTOLOAD` Example

```
@funcs = qw(red yellow blue);

sub red    { ... }   # etc.

sub AUTOLOAD {
   my ($package, $function) = ($AUTOLOAD =~ /(.*)::(.*)/);
   my $correct = approximate_match($function, \@funcs);
   if (defined &$correct) {
     return &$correct(@_);
   } else {
     die "Function $function unknown; try [@funcs]\n";
   }
}
```

- Now if you do

```
blug(...);
```

it just calls `blue` for you with the same arguments as if nothing was wrong

- Inside of `AUTOLOAD`, `@_` contains the regular function arguments

Simple AUTOLOAD Example

```
        blug(...);              # Calls blue() instead
```

- A few years ago I gave this class at YAPC
- Someone in the audience asked "Are you sure this is a good idea?"
  - No, it's a completely terrible idea
- Unfortunately, Dave Cross was also in the audience
- The result was `Symbol::Approx::Sub`
- At least the documentation says:

Why you would ever want to do this is a complete mystery to me.

Magic `goto`

- These two are *almost* the same:

```
        sub AUTOLOAD {                  sub AUTOLOAD {
          return &blue;                     goto &blue;
        }                               }
```

- On the right is *magic goto*.
- Calls `blue` normally
- But `blue` returns directly to `AUTOLOAD`'s caller
- Just as if `AUTOLOAD` had never been called
- Magic `goto` is perfect for autoloaded functions

Brief Digression: Tracing Again

- In Part I, we saw a trace utility
  - It wrapped each function inside a tracing wrapper:

```
my $real_func = \&*$func_name;
*{$caller . "::$func_name"} = sub {
  print "$func_name(@_)\n";
  $real_func->(@_);
};
```

- If `$real_func` depends on `caller`, it could get confused
- It will notice that it was called from the wrapper, not from the real caller
- Solution:

```
{$caller . "::$func_name"} = sub {
  print "$func_name(@_)\n";
  goto &$real_func;
};
```

Case-Insensitive Function Calls

```
sub closethewindow { ... }

sub AUTOLOAD {
  my ($package, $func) = ($AUTOLOAD =~ /(.*)::(.*)/);
  my $true_func = join '::', $package, lc $func;
  goto &$true_func if defined &$true_func;
  croak "Undefined subroutine &$AUTOLOAD";
}
```

- `defined &foo` checks to see if the function exists
- Now you can call `closeTheWindow`
- or `CloseTheWindow`
- or `CLOSETHEWINDOW`
- It doesn't matter.

Function Call Caching

```
sub closethewindow { ... }

sub AUTOLOAD {
  my ($package, $func) = ($AUTOLOAD =~ /(.*)::(.*)/);
  my $true_func = join '::', $package, lc $func;
  if (defined &$true_func) {

    *$AUTOLOAD = \&$true_func;
    goto &$AUTOLOAD;
  }
  croak "Undefined subroutine &$AUTOLOAD";
}
```

- First time we call `CloseTheWindow`, alias the two function names
- Second time, we get `CloseTheWindow` directly
- There's that magic glob again
- `goto &$AUTOLOAD` and `*$AUTOLOAD = ...` are common idioms

Typical `AUTOLOAD` Use: Accessor Methods

```
package Object;
my @attrs = qw(color size price ....);  # 637 of these
my %is_attr = map {$_ => 1} @attrs;

sub new {
  my $pack= shift;
  my %self;
  @self{@attrs} = @_;
  bless \%self => $pack;
}

...
```

Direct Emulation of Accessors

```
my @attrs = qw(color size price ... );  # 637 of these
my %is_attr = map {$_ => 1} @attrs;

...

sub AUTOLOAD {
  my $self = shift;
  my ($package, $method) = ($AUTOLOAD =~ /(.*)::(.*)/);
  unless ($is_attr{$method}) {
    croak "No such attribute: $method; aborting";
  }

  my $val = $self->{$method};
  $self->{$method} = shift if @_;
  $val;
}
```

- What for?

```
$object->color('red');     # set object's color
$size = $object->size;     # fetch object's size
```

- No need to define 637 separate accessor functions
- All handled by one `AUTOLOAD`
- (Warning: This method also gets called for `DESTROY` and others)

Caching Accessor Methods

- Calling via `AUTOLOAD` incurs overhead
- Aliasing also incurs some overhead
- We can avoid almost all overhead and win the tradeoff:

```
sub AUTOLOAD {

  # ... as before; set up $method ...

  my $code = q{
    sub {
      my ($self) = @_;
      my $val = $self->{METHODNAME};
      $self->{METHODNAME} = shift if @_;
      $val;
    }
  };

  $code =~ s/METHODNAME/$method/g;

  *$AUTOLOAD = eval $code;
  goto &$AUTOLOAD;
}
```

- The first time, it constructs and compiles the code for the method
- Second time, the method is called directly with no `AUTOLOAD`
- No overhead!
- There's that magic glob again.

Autoloading From a File

- If there’s a lot of autoloaded code, it makes more sense to keep it in a file

```
sub AUTOLOAD {
   my $file = $AUTOLOAD;
   $file =~ s{::}{/}g;
   $file = "/src/app/autoloaded/$file.al";

   open my $fh, "< $file"
     or croak "Couldn’t load code from $file: $!; aborting";

   my $code;
   { local $/; $code = <$fh> }
   *$AUTOLOAD = eval $code;
   goto &$AUTOLOAD;
}
```

- The first time the function is called, the code is loaded from the file
- Code for `Some::Module::foo` is in `.../Some/Module/foo.al`
- Code compiled and installed in symbol table as before
- Second time, the function is called directly - no overhead
- Now you know what `AutoLoader` does - invented for `POSIX`

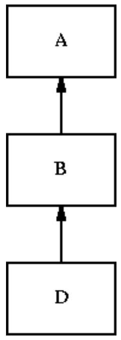
Generating Functions Dynamically

- In this example, compiling the code repeatedly is a waste of time
- Only one variable changes in each accessor
- Perl can construct functions that share code without recompiling

```
sub AUTOLOAD {

  # ... as before; set up $method ...

  my $code = sub {
      my ($self) = @_;
      my $val = $self->{$method};
      $self->{$method} = shift if @_;
      $val;
    };

  *$AUTOLOAD = $code;
  goto &$AUTOLOAD;
}
```

- The new method is a *closure*
- It refers to a private variable, `$method`
- When `AUTOLOAD` returns, only the new method has a reference to `$method`
- The new methods all share code, but each has its own private `$method` variable
- Method code is compiled only once, along with the rest of your program

NEXT.pm



- Consider this class inheritance structure:
- Now consider `D::DESTROY`
  - We would like `D::DESTROY` to call `B::DESTROY` (if there is one)
  - Moreover `B::DESTROY` should call `A::DESTROY` (ditto)
- We can accomplish that this way:

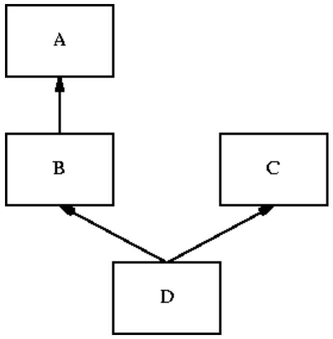
```
# Package D
sub DESTROY {
  my $self = shift;
  # Do various destructions here
  $self->SUPER::DESTROY;
}
```

- `SUPER::DESTROY` means "call `DESTROY`"
  - If `B::DESTROY` also calls `SUPER::DESTROY`, everything works as it should

NEXT.pm

```
$self->SUPER::DESTROY;
```

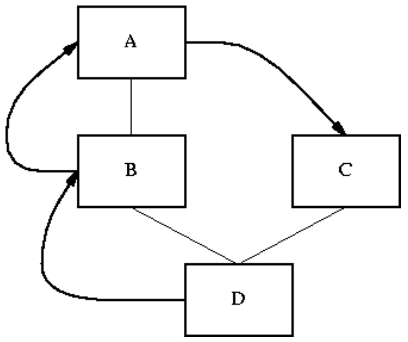
- But what if `$self` has more than one base class?
  - Which `DESTROY` method is called?
  - Only the first one, it turns out.



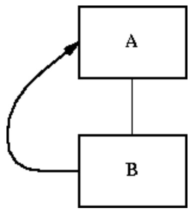
- Suppose each `DESTROY` calls `SUPER::DESTROY`
  - Unfortunately, that's not enough
  - `D::DESTROY` calls `B::DESTROY`
  - `B::DESTROY` calls `A::DESTROY`
  - `C::DESTROY` is never called

NEXT.pm

- `NEXT` is the solution to this problem
- Each method calls `->NEXT::method`
- This magically redispatches to the correct ’next’ method
- For example:

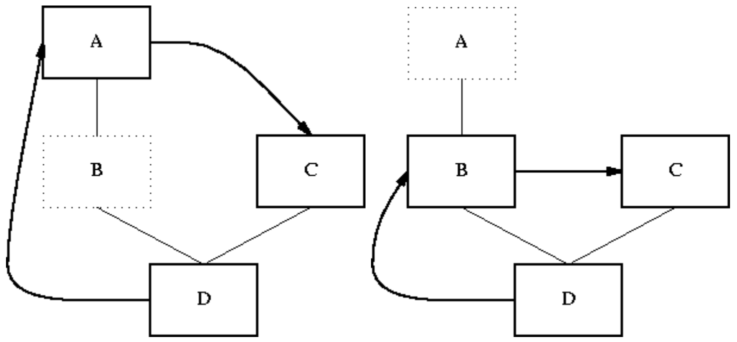


- Note that when `$self->NEXT::method` in class `A` depends on the class of `$self`
  - If `$self` is a `D`, then `A` dispatches to `C`
  - If `$self` is a `B`, then `A` dispatches nowhere
- Damian Conway invented this



NEXT.pm

- If some of the methods are missing, `NEXT` figures that out:



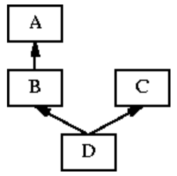
- But how does this all work?
  - `NEXT` is essentially a big fat `AUTOLOAD`
- `->NEXT::method` wants to call `NEXT::method`
  - But there isn’t one, so it calls `NEXT::AUTOLOAD` instead
  - `NEXT::AUTOLOAD` examines the inheritance hierarchy
  - Figures out the correct ’next’ method
  - Jumps there with magic `goto`

NEXT.pm

- Here's a simplified version
- First, a utility function:

```
sub class_structure {
  my $start = shift;
  my $prev;

  my @todo = ($start);
  my %next;
  while (@todo) {
    my $cur = shift @todo;
    $next{$prev} = $cur if defined $prev;
    unshift @todo, @{"$cur\::ISA"};
    $prev = $cur;
  }
  \%next;
}
```

- Given a class name, this returns a hash of 'next' classes



- Given `D` it returns

```
{ D => B,  B => A,  A => C,  C => undef }
```

- Given `B` it returns

```
{ B => A, A => undef }
```

NEXT.pm

```
sub AUTOLOAD {
  my ($self_class) = ref $_[0] || $_[0];
  my $cs = class_structure($self_class);

  my $caller_class = caller;
  my $next_class = $caller_class;

  my (undef, $method) = ($NEXT::AUTOLOAD =~ /(.*)::(.*)/);

  do {
    $next_class = $cs->{$next_class};
  } while defined $next_class
       && not defined &{"$next_class\::$method"} ;

  if (defined $next_class) {
    goto &{"$next_class\::$method"};
  } else {
    return;
  }
}
```

- We find out the class that the target object is in (`$self_class`)
- We get the next-class table for that class (`$cs`)
- We figure out where we were called from (`$caller_class`)
- We scan `$cs` until we find a new class that has the method we want
- Then we go to it

NEXT.pm

- That version returns silently if there is no ’next’ method
- You might like it to die instead
- For example, an `AUTOLOAD` might decide it’s not prepared to emulate a certain function
- It wants to delegate control to the next `AUTOLOAD`, which might handle it
- But if there are no more `AUTOLOAD`s, it should croak, since nobody will handle it
- `$self->NEXT::ACTUAL::method(...)` will croak if there is no ’next’ method
- The code is simple

NEXT.pm

- `$self->NEXT::ACTUAL::method(...)` will croak if there is no ’next’ method

```
sub AUTOLOAD {
  my ($self_class) = ref $_[0] || $_[0];
  my $cs = class_structure($self_class);

  my $caller_class = caller;
  my $next_class = $caller_class;

  my ($my_class, $method) =
        ($NEXT::AUTOLOAD =~ /(.*)::(.*)/);

  do {
    $next_class = $cs->{$next_class};
  } while defined $next_class
       && not defined &{"$next_class\::$method"} ;

  if (defined $next_class) {
    goto &{"$next_class\::$method"};
  } else {
    croak qq{Can’t locate object method "$meth"
                   via package "$self_class"};
      if $my_class eq ’NEXT::ACTUAL’;
    return;
  }
}

@NEXT::ACTUAL::ISA = (’NEXT’);
```

`Shell.pm`

- One final hack:

```
sub AUTOLOAD {
  my ($pack, $func) = ($AUTOLOAD =~ /(.*)::(.*)/);
  qx{$func @_};
}
```

- Now you can write Perl programs that look like shell scripts:

```
$passwd = cat("</etc/passwd");
print $passwd;

sub ps;
print ps -ww;

cp("/etc/passwd", "/tmp/passwd");
```

- This is due to Larry Wall
- I omitted a lot of details here
- See `Shell.pm` for the actual implementation

Cantrips

Returning a False Value

```
sub foo {
  ...
  return undef;                # False
}

if (@result = foo(...)) { ... }
```

- Oops. `undef` is *not* false in a list context!
- `@result` has one element, which is `undef`

```
if (@result) { ... }        # Yes!
```

Returning a False Value

- Solution:

```
sub foo {
  ...
  return;
}
```

- Returns `undef` in scalar context.
- Returns empty list in list context.

The Self-Replacing Stub

- We've already seen

```
...
require Carp;
Carp::croak(...);
...
```

as a way to defer loading of a module until it's needed.

- Alternative: use `AUTOLOAD`

```
sub AUTOLOAD {
  if ($AUTOLOAD =~ /::croak$/) {
    require Carp;
    goto &Carp::croak;
  }
}
```

The Self-Replacing Stub

- Here's another way:

```
sub croak {
  require Carp;

  *croak = \&Carp::croak;
  goto &croak;
}
```

- There's that magic glob again.
- Also magic `goto`
- But also see `autouse.pm`

Schwartzian Transform

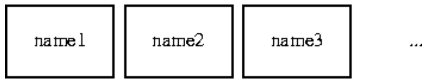
- Sort list of items by some *non-apparent* feature
- Example: Sort filenames by last-modified date
- Obvious method is very wasteful:

```
sort { -M $b <=> -M $a } (readdir D);
```

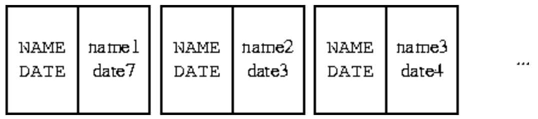
- Calls `-M` over and over on the same files
- Another idea:
  1. Construct data structure with both names and dates
  2. Sort by date
  3. Throw away dates

Schwartzian Transform

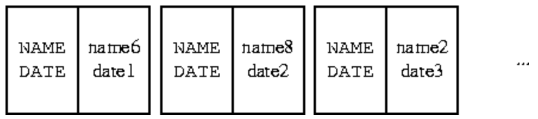
```
@names = readdir D;
```



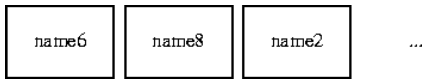
```
@names_and_dates =
  map { { NAME => $_, DATE => -M $_ } }
  @names;
```



```
@sorted_names_and_dates =
  sort { $b->{DATE} <=> $a->{DATE} }
  @names_and_dates;
```



```
@sorted_names =
  map { $_->{NAME} }
  @sorted_names_and_dates;
```



Schwartzian Transform

```
@sorted_names =
  map { $_->[0] }
  sort { $b->[1] <=> $a->[1] }
  map { [ $_, -M $_ ] }
  readdir D;
```

- Caveat: Do not optimize without benchmarking!

```
User   System Total
5.11 + 6.83 = 11.94             Naive sort
7.37 + 0.82 =  8.19             Schwartzian transform
```

- Donald E. Knuth (famous wizard) says (quoting R. W. Floyd):

Premature optimization is the root of all evil.

Schwartzian Transform

Well-known to Unix shell programmers:

```
# Sort file names by file size

ls -l | sort -n +4 | awk '{print $NF}'

# Sort output of SOMETHING from most frequent to least

SOMETHING | uniq -c
  | sort -nr | awk '{$1=""; print}'
```

Debug Printing of Strings

```
if (/carrots$/) { die }
```

- But it didn’t die! Why not?
- Try the debugger:

```
DB<119> p $_;
I like carrots
```

- Pull your hair out.
- Or, instead:

```
DB<119> p "<$_>";
<I like carrots            >
```

- Oho.
- The *terminal program* should have taken care of this!

Debug Printing of Lists

```
@t = (’x’, ’ ’, ’=’, ’ ’, ’3.4’, ’& ’, ’y’, ’’, ’=’, ’’, ’5’)
```

- Now `print @t` yields

```
x = 3.4& y=5
```

- Hard to tell what the list elements are!
- `print "@t"` is even worse!

```
x   =   3.4 &  y  =  5
```

- Solution:

```
$" = ’)(’;
print "(@t)";

(x)( )(=)( )(3.4)(& )(y)()(=)()(5)
```

?:?:?:

- Most folks know about the `?:` operator

```
*{$p . '::' . $n} = (ref $v ? $v : \$v);
```

- It's a compact version of an `if-else` block
- What if you want a compact version of an `if-elsif-else` block?

```
sub sign {
  my $x = shift;
  if ($x < 0) { return -1 }
  elsif ($x == 0) { return 0 }
  else { return +1 }
}
```

- No problem:

```
sub sign {
     $_[0] <  0 ? -1 :
     $_[0] == 0 ?  0 :
                   1 ;
}
```

- Everything is as it should be
- The precedence is fine, the short-circuiting is fine
- The folks who designed the `?:` operator are very smart
- So chain together as many as you want

Booleanumbers

```
sub delete_files {
  my ($dir) = @_;
  opendir my $dh, $dir or return;
  my $deleted = "0e0";
  for (readdir $dh) { ++$deleted if unlink }
  return $deleted;
}

unless (delete_files(...)) { die... }

$num_deleted = delete_files(...);
```

- Function only returns false on an error
- Even when it returns 0, it returns true
- `"0e0"` is zero, but true
- Also `"0 but true"` return from `ioctl`
- `DBI` uses a similar trick

Local Effects

- `local` confines a change to a block
- We saw:

```
{ local *F = \&VeryLongName::SomeFunction;

  F(...);
}

{ local $| = 1;
  $rc = print $self "";
}

{ local $/; $code = <$fh> }
```

- Wouldn't it be nice to be able to do this:

```
{ local chdir $DIR;
  ...
}
# Old directory is restored here
```

Local Effects

- Here's the idea:

```
{ my $temporary = LocalChdir->chdir_to($DIR);
  ...
}
```

- When control exits the block, `$temporary` will be destroyed
- We can rig up `LocalChdir::DESTROY` to move back to the old directory

```
package LocalChdir;
use Cwd;

sub chdir_to {
  my ($package, $new_dir) = @_;
  my $old_dir = cwd();
  return unless chdir($new_dir);
  bless { DIR => $old_dir } => $package;
}

sub DESTROY {
  my $dir = $_[0]{DIR};
  chdir($dir)
    or croak("Couldn't return to '$dir' on block exit: $!");
}
```

Local Effects

- This trick is widely used:

```
use SelectSaver;
{  my $saver = SelectSaver->(FH);
   # FH is selected
}
# old handle is selected
```

- Or:

```
use Hook::LexWrap;
{
   my $temporarily = wrap 'myfunction',
                       post => sub { print "[post:@_]\n" },
                       pre  => sub { print "[pre: @_]\n  "};
   # Function is wrapped
}
# Function is no longer wrapped
```

Selecting n Different Things

```
while (keys %h < $n) {
  $h{select_thing()}++;
}
@things = keys %h;
```

- In scalar context, `keys %h` is super-efficient.
- No, it does not count the keys one at a time.

Dinner Time!

Thanks very much for attending my class

The evaluation form is at

```
        http://perl.plover.com/class/eval.cgi
```

Or you can send me mail with questions or comments whenever you like

Other Resources

- *Perl Cookbook*, Christiansen and Torkington. O’Reilly and Associates.
- *Perl Paraphernalia* web site. http://perl.plover.com/
- *Object-Oriented Perl*, Damian Conway. Manning Publications.
- *Advanced Perl Programming* (2nd Edition), Simon Cozens. O’Reilly and Associates.
- Perl 6 development web site. http://dev.perl.org/perl6/

Bonus Slides Not in the Talk Anymore

- Talks evolve over the years
- Things move in, other things move out
- I still have the slides for the stuff that moved out
- You might as well see them if you’re interested

Biographical Note

- I first did this class in 1999
- It used to say:

Disclaimer

I am not personally a wizard.

Biographical Note

- But last year at YAPC Larry said he thought I *was* a wizard
- Says Larry:

"One of the benefits of Perl culture is that anyone can become a wizard regardless of age, race, gender, or programming ability."

Making Things Appear to Be What They're Not

Part III: Overloading

(Eliminated summer 2000 in favor of Autoloading)

Overloading Overview

- In *overloading*, you redefine the effect of the standard Perl operators like + and `.` to have a special meaning for objects in a certain class.
- Operator applications are transformed into method calls.
- Syntax:

```
package MyClass;
use overload '+' => \&myadd,
             '-' => \&mysubtract,
             ...
             ;
```

- Now `$obj1 - $x` turns into

```
$obj1->mysubtract($x);
```

Overload Method Call Summary

- Argument 1 is always an object of the appropriate class, as with any method
- On two objects of the same type, you get the objects in the same order:

```
$obj1 - $obj2                mysubtract($obj1, $obj2);
$obj2 - $obj1                mysubtract($obj2, $obj1);
```

- When operating on an overloaded object and an unoverloaded value, the object is *always* the first argument:

```
$obj1 - $x                   mysubtract($obj1, $x);
$x    - $obj1                mysubtract($obj1, $x, 1);
```

- On two overloaded objects of different types, the left-hand argument determines whose method will be called:

```
$obj1 - $OBJX                mysubtract($obj1, $OBJX);
$OBJX - $obj1                Xcombine($OBJX, $obj1);
```

Overloading: Normal uses

- `BigInt`, `BigFloat`, `Complex`, etc.
- Vectors, `Bit::Vector`, etc.
- I tried to think of more, but actually overloading is overrated.

Overloading: Example

```
package Vector3;
use Carp;

use overload '+' => \&add,
             '*' => \&dotproduct,
             'x' => \&crossproduct,
            ;

sub new {
  my $package = shift;
  $package = ref $package || $package;
  croak "Usage: new(x,y,z)" unless @_ == 3;
  my %self;
  @self{'X','Y','Z'} = @_;
  bless \%self => $package;
}

...
```

Overloading: Example

```
sub add {
  my ($vec1, $vec2) = @_;
  unless (ref $vec1 && $vec1->isa('Vector3')
       && ref $vec2 && $vec2->isa('Vector3')) {
    croak "Invalid vector addition";
  }
  $vec1->new(map {$vec1->{$_} + $vec2->{$_}}  qw(X Y Z));
}
```

Overloading: Example

```
sub dotproduct {
  my ($vec1, $vec2, $rev) = @_;

  if (ref $vec2 && $vec2->isa('Vector3')) {
    my $dp = 0;
    for (qw(X Y Z)) {
      $dp += $vec1->{$_} * $vec2->{$_};
    }
    return $dp;
  } elsif (! defined ref $vec2) {   # It's a scalar
    return $vec1->new(map {$vec2 * $vec1->{$_}} qw(X Y Z));
  } else {
    croak "Invalid vector scalar multiplication";
  }
}

sub crossproduct {
   ...
}
```

Overloading: Bizarre Example

- We’re going to detect Y2K bugs.
- Perl `localtime` function is very badly designed.

```
(..., $year, ...) = localtime(...);

$q =  "$mon/$day/$year";                               # wrong
$q =  "$mon/$day/" . sprintf('%02d', $year % 100);    # RIGHT

print "The year is 19$year.\n";                        # wrong
print "The year is 19" . $year . ".\n";                # wrong
print "The year is ", 1900+$year, ".\n";               # RIGHT
```

Overloading: Y2K Detection Example

- Strategy:
  - Override `localtime` to call our fake `localtime` function
  - Our function will return the usual values, except...
  - The `year` item will be a special object...
  - Which will be overloaded to call `carp` if it is concatenated with `"19"`

Overloading: Y2K Detection Example

```
package y2k;
use Carp;
use overload '.'  => \&concat,
             '0+' => \&to_num,
           ;

sub import {
  my $caller = caller;
  *{$caller . '::localtime'} = \&fake_localtime;
  *{$caller . '::gmtime'   } = \&fake_gmtime;
}
```

- There's that magic glob again.

Overloading: Y2K Detection Example

```
package y2k;
...
sub fake_localtime {
  unless (wantarray) {
    return @_ ? localtime(@_) : localtime();
  }
  my @lt = @_ ? localtime(@_) : localtime();
  $lt[5] = { YEAR => $lt[5] };
  bless $lt[5] => 'y2k';
  @lt;
}
```

Overloading: Y2K Detection Example

```
package y2k;
...
sub to_num {
  my ($year) = @_;
  return $year->{YEAR};
}

sub concat {
  my ($y2k, $s, $rev) = @_;
  carp("Detected possible Y2K problem");
  my $year = sprintf("%02d", $y2k->{YEAR} % 100);
  $rev ? $s . $year : $year . $s;
}
```

- Or use `Syslog` instead of `carp`.

Overloading: Y2K Detection Example

- Program now croaks on `$year % 100`, `$year + 1900`, etc.
- One solution: Just add `modulus`, `addition`, etc. methods.
- Another solution:

```
package y2k;
...
use overload 'nomethod' => \&default;
...
sub default {
  my ($y2k, $arg, $rev, $op) = @_;
  my $y = $y2k->{YEAR};
  my $expr = $rev ? "$arg $op $y" : "$y $op $arg";
  eval $expr;
}
```

Overloading: Y2K Detection Example

- Another solution uses a *dispatch table*:

```
{ my ($year, $arg);

  %methods = (
     '+' => sub { $year + $arg },
     '%' => sub { $year % $arg },
    'r%' => sub { $arg % $year },
     ...
  );

  sub default {
    my ($y2k, $a, $rev, $op) = @_;
    my $code = $rev
      ? ($methods{"r$op"} || $methods{$op})
      :                       $methods{$op}
      ;
    croak "No method defined for y2k object for operation `$op
      unless $code;
    $arg = $a;
    $year = $y2k->{YEAR};
    &$code;
  }
}
```

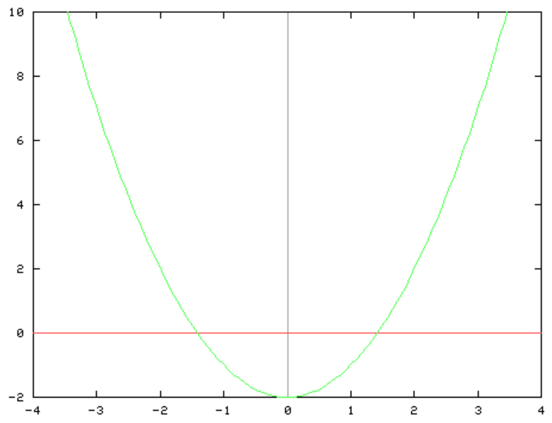
Big Techniques

(Eliminated in favor of autoloading)

Big Technique #1: Newton-Raphson Method

- Almost everyone has to work with numbers
- Numerical computation techniques are an entire field
- Most techniques are special-purpose
- This one is an exception

`sqrt()`

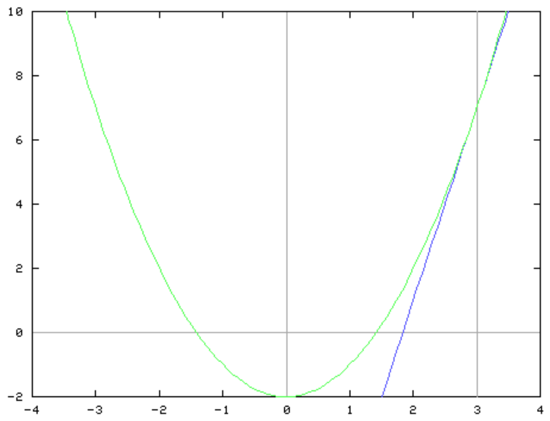


- How does the Perl `sqrt()` function work?
- Probably uses something like the *Newton-Raphson Method*
- To compute `sqrt(2)`, we need to solve the equation

$$x^2 - 2 = 0$$

- That's where this parabola crosses the *x* axis

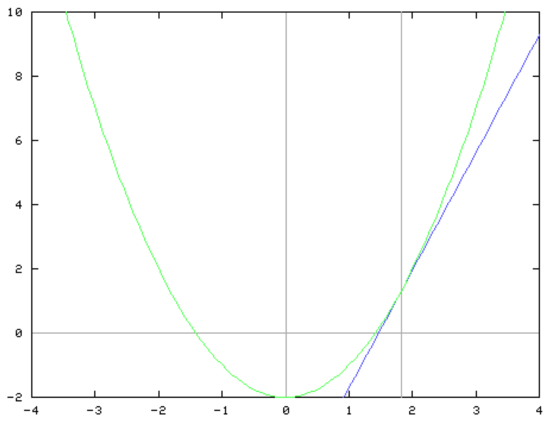
Newton-Raphson Method



- *Guess* a solution (yes, just guess!)
- Tangent line through that point will locate a better guess
- Repeat as desired

- Repeat as desired

Newton-Raphson Method



- Math and code turn out to be very simple in general
- Even simpler for this particular case

Square Roots with Newton-Raphson Method

```
sub square_root {
  my ($n, $e) = @_;
  $e ||= 0.00001;
  my $guess = $n;    # Yes, just guess!

  while (abs(($guess*$guess - $n)/$n) > $e) {
    $guess = ($guess + $n/$guess)/2;
  }
  return $guess;
}
```

- That’s all!

Solve Any Equation With Newton-Raphson

- Suppose you want to solve $f(x) = N$
- Step 1: Compute the derivative $d(x)$
  - Or get the math expert down the hall to do it
- Then the answer is:

```
sub solve {
  my ($N) = @_;
  my $g = 1;    # Substitute a reasonable guess here
  until (the guess is good enough) {
    $g -= (f($g) - $N) / d($g);
  }
  return $g;
}
```

- Warnings:
  - Initial guess must be reasonable
  - Method doesn’t *always* work

Solve Any Equation With Newton-Raphson

- Example: Financial computations
- A principal *P* invested for time *N* at rate of return *i* grows to:

```
    $F = $P * (1+$i)**$N ;
```

- Question: How long before I have a million dollars?
- (Given *F*, *P*, and *i*, compute *N*)
- The math expert down the hall says that the derivative is

```
      $P * (1+$i)**$N * log(1+$i)
```

- Looks nasty, but that's OK, just plug it in

Newton-Raphson: Financial Computations

```
        sub how_long {
          my ($P, $i, $F) = @_;
          my $g = 1;  # Initial guess
          my $d = 1;
          until ($d/$g < 0.000001) {
            $d =   ($P * (1+$i)**$g - $F)
                 / ($P * (1+$i)**$g * log(1+$i));
            $g -= $d;
          }
          return $g;
        }
```

- Example: `how_long(10000, 0.065, 1000000)` is 73.1271913100701
- $10,000 invested at 6.5% interest becomes $1,000,000 after 73.12 years

Big Technique #2: Caching

- Makes programs faster
- Exchanges space for time
- When a cached function is called, its return value is saved
- When called again with same arguments, the saved value is returned

Caching

- Very commonly used
- Example: Your local DNS server caches the responses it gets from other DNS servers
- Another example: Converting RGB values to CMYK values:

```
sub cmyk {
  my ($r, $g, $b) = @_;
  my ($c, $m, $y) = (1-$r, 1-$g, 1-$b);
  my $k = $c < $m ? ($c < $y ? $c : $y)
                  : ($m < $y ? $m : $y);  # Minimum
  for ($c, $m, $y) { $_ -= $k }
  [$c, $m, $y, $k];
}
```

- Many image formats (including GIF) have many pixels that are the same color.
- This recomputes the same CMYK values over and over.

Caching

- Faster version:

```
{
  my %cmyk;

  sub cmyk {
    my $key = join ',' , @_;
    return $cmyk{$key} if exists $cmyk{$key};
    $cmyk{$key} = real_cmyk(@_);
  }

  sub real_cmyk {
    # as before ...
  }
}
```

Memoizing

- *Memoizing* is the process of converting a function to use caching.
- It can be done *automatically*
- Here’s how you do it:

```
use Memoize;
memoize 'cmyk';

sub cmyk { ... as before ... }
```

- That’s all!
- I’d love to tell you all about the internals, but we don’t have time
- You can read my TPJ article about it on my web site.

http://perl.plover.com/Memoize/

Memoizing

- Memoizing is a really useful tool to have in your toolbox
- Program too slow? Try sprinkling in a little memoization. It’s cheap and easy.
- Need to profile? Try memoizing. If it works, rewrite the function you memoized; if not, try another function.
- Worried about recursion inefficiencies? Memoization is often a cheap and effective alternative to rewriting in iterative style.
- Continued...

Memoizing

- Memoize slow functions like `gethostbyname`.
- Memoize to a permanent database and speed up your function *forever*.
- Same technique can be adapted to make a simple profiler
  - Or call counter
  - Or call-graph generator
  - See Philippe Verdret’s `Hook::PrePostCall` module
- Memoization is *impossible* in C

Big Technique #3: Iterators

- An iterator is an object interface to a list
  - Supports a ‘next’ operation to generate the next item when it is needed
- Why?
  - The list might be enormous
  - Might take a long time to come up with list elements
  - You don’t know in advance how many you will want
  - You can pass the object around so it can be used by anyone who needs it

Iterators

- This is not new: A filehandle is an iterator!
  - It encapsulates a list of strings (the lines)
  - The `<...>` operation requests the next string
  - Other examples: `each`, `readdir()`, `glob`

Iterator Example

- Suppose you want to generate strings of a certain form
- I got this example from a biologist
- He wanted `"AT(GC)A(TA)"` to become `ATGAT`, `ATGAA`, `ATCAT`, `ATGCAA`.
- He had built a recursive subroutine to generate all the strings of a given form
- It took a long time to run and generated a uselessly large list
- Iterators are a better solution
- As an example, will expand `"foo-#-bar#"` instead:
  - `foo-0-bar0`
  - `foo-0-bar1`
  - ...
  - `foo-9-bar8`
  - `foo-9-bar9`

Iterator Example

```
sub make_iterator {

  my @tokens = split /(\#)/, shift();
  my $n_digits = grep {$_ eq '#'} @tokens;
  my $digits = '0' x $n_digits;

  return sub {
      my $result;
      my $d = 0;
      for my $t (@tokens) {
        if ($t eq '#') {
          $result .= substr($digits, $d++, 1);
        } else {
          $result .= $t;
        }
      }

      $digits++;
      if (length $digits > $n_digits) { # Overflow?
        $digits = '0' x $n_digits;      # Reset
      }

      return $result;
    };
}
```

- Anonymous subroutine is a *closure*
- `my` variables are *captured* by the closure
- Each call to `make_iterator` constructs a new closure with new private state variables

Iterator Example

```
my $it = make_iterator('foo-#-bar#');

for (1..105) {
  my $s = $it->();
  print "$s\n";
}

# Prints foo-0-bar0, foo-0-bar1,
#        ...,
#        foo-9-bar8, foo-9-bar9, ...
```

- Easy change to make it stop and return `undef` instead of starting over.
- Construct many iterators that all operate independently.
- Pass iterators to functions, store in data structures.

Iterator Operations

- An iterator is just as good as a list:

```
while (defined ($item = $iterator->())) {
  # Do something with this $item
}
```

Iterator Operations

- If the iterator returns the list items in some canonical order, you can do this:

```
sub both {
  my ($it1, $it2) = @_;
  my ($a, $b) = ($it1->(), $it2->());

  sub {
    return undef unless defined $a || defined $b;
    my $rv;
    if ($a lt $b || ! defined $b) {
      $rv = $a;
      $a = $it1->();
    } if ($b lt $a || ! defined $a) {
      $rv = $b;
      $b = $it2->();
    } else {          # $a eq $b
      $rv = $a;
      ($a, $b) = ($it1->(), $it2->());
    }
    return $rv;
  }
}
```

- This function works for *any* iterators that return items in alphabetical order
- If an iterator represents a database query, this is the *OR* operation

More Applications of Iterators

- Database lookups can return an iterator that generates solutions on demand
- Tree searches can return an iterator that generates solutions on demand
- Search functions of any sort can ..
- **Important note**:
  - This is just a technique for saving the state of a partially-completed function...
  - ...and restarting it later
  - Not usually considered an easy thing to do!

Big Technique #4: State Machines

- In a *state machine*, the program tracks a ‘current state’
- It has a table that says, for each possible state and each possible input type:
  - What state to be in next
  - An action to perform
- For example, suppose we’re writing an NNTP server:
- In state `START`:
  - call `&say_hello`, goto `MAIN`
- In state `MAIN`:
  - `GROUP` command: call `&cmd_group`, goto `MAIN`
  - `QUIT` command: call `&cmd_quit` and goto ...
  - `POST` command: call `&cmd_post`, goto `HEADER`
  - ...
- In state `HEADER`:
  - Blank line: call `&article_save_header`, goto `BODY`
  - `.`: goto `ARTICLE_FINISH`
  - Other: store line, goto `HEADER`
- In state `BODY`:
  - `.`: goto `ARTICLE_FINISH`
  - Other: store line, goto `BODY`
- In state `ARTICLE_FINISH`:
  - call `&article_check_and_post`, goto `MAIN`

Implementing State Machines in Perl

- The easiest way is with a hash table.
- The keys are the state names.
- The values have:
  - The action to perform (a coderef)
  - The name of the next state
  - Other information if appropriate

State Machines For NNTP

```
%machine = (
  START => { DEFAULT=> [ \&say_hello, MAIN, ],
           },
  MAIN  => { group =>  [ \&cmd_group, MAIN],
             quit  =>  [ \&cmd_quit,  MAIN],
             post  =>  [ \&cmd_post,  HEADER],
             ...
           },
  HEADER =>{ BLANK =>  [ \&article_save_header, BODY],
             DOT   =>  [ undef,                 ARTICLE_FINISH
             DEFAULT=> [ \&store_line,          HEADER ],
  ...
);
```

- Associated with each state is a *transition table*
- Keys in transition table represent *input conditions*

State Machines For NNTP

```
%machine = (
  START => { DEFAULT=> [ \&say_hello, MAIN, ], },
  MAIN  => { group =>  [ \&cmd_group, MAIN],
  ... } ... );

BEGIN { $STATE = 'START' }

sub run_machine {
  for (;;) {
    my $t_table = $machine{$STATE};
    my ($input, @args) = get_input();
    my ($action, $next_state) =
      @{$t_table->{$input} || $t_table->{DEFAULT}};
    unless defined($next_state) {
      die "No transition defined for state $STATE, input $inpu
    }
    $action->(@args) if $action;
    $STATE = $next_state;
  }
}
```

State Machines Are Very Easy to Read!

```
sub run_machine {
  for (;;) {
    my $t_table = $machine{$STATE};
    my ($input, @args) = get_input();
    my ($action, $next_state) =
      @{$t_table->{$input} || $t_table->{DEFAULT}};
    unless defined($next_state) {
      die "No transition defined for state $STATE, input $inpu
    }
    $action->(@args) if $action;
    $STATE = $next_state;
  }
}
```

- For something as complicated as NNTP, this is very simple code!
- All the details are in the table, which is tidy and compact
- Brian Kernighan (noted wizard) says:

Capture regularity with code, irregularity with data.

Big Technique #5: Building a Replacement Debugger

- There’s nothing special about the perl debugger
- It’s just another module
- When you run `perl -d ...` it loads `perl5db.pl`
- Code in `perl5db.pl` is enlightening

Why Build a Replacement Debugger?

- Obvious tactic: Copy `perl5db.pl`, modify slightly, use.
- But there are some non-obvious tactics
- The debugger isn't *just* an ordinary module
- In debug mode, Perl enables special features
- To use: Name the module `Devel::Something`
- Run with `perl -d:Something` to automatically load

Debugger Features

- Lots of functions for haruspication
- See `perldebguts` (or `perldebug`) for fullest details

- `@{"::_<foo.pl"}` contains the source code of `foo.pl`
- `%{"::_<foo.pl"}` contains breakpoints and actions
- `%DB::sub` contains subroutine start-end information
- `DB::DB()` is called before each executed line
- `caller()` returns current package, filename, line as usual, also sets `@DB::args`

Trivial Debugger

```
package Devel::Count;

sub DB::DB { ++$count }

END { print "Total statements: $count\n" }
```

- Now `perl -d:Count program.pl` prints out:

```
Total statements: 286
```

Trace Execution

- Occasionally-asked question:
- "How can I emulate the behavior of the Bourne shell `-x` option?"
- Here's one way:

```
package Devel::Trace;

sub DB::DB {
  my ($p, $f, $l) = caller;
  my $code = \@{"::_<$f"};
  print STDERR ">> $f($l) $code->[$l]";
}
```

- Now `perl -d:Trace sample.pl` prints out:

```
>> sample.pl(1) for (1 .. ($ARGV[0] || 12)) {
>> sample.pl(2)   next unless $_ % 12;
>> sample.pl(3)   print "";
>> sample.pl(1) for (1 .. ($ARGV[0] || 12)) {
(etc.)
```

Examine Source Code

```
package Devel::Dumpcode;

sub DB::DB { }    # Do nothing special

sub main::source_of_function {
  my $package = caller;
  $function = $package . '::' . shift();
  my ($file, $start, $end) =
    $DB::sub{$function} =~ /(.*):(\d+)-(\d+)/;
  @{"::_<$file"}[$start..$end];
}
```

- Now the program can do

```
print source_of_function('foo')
```

to print out the source of function `foo`

- Print code to file, invoke editor, reload, `eval`

Simple Profiler

- `Devel::DProf` is complicated and hard to use
- But building a simple profiler is *easy*

```
package Devel::Profile;

sub DB::DB {
  my ($package, $file) = caller();
  my ($subroutine) = (caller(1))[3];
  return if $subroutine  eq '(eval)';
  $subroutine = "<$file>" unless defined $subroutine;
  ++$count{$subroutine};
}

END {
  for $subr (sort {$count{$b} <=> $count{$a}} (keys %count)) {
    printf STDERR "%8d %s\n", $count{$subr}, $subr;
  }
}
```

- Output:

```
798 main::page
 66 </usr/local/bin/perldoc>
 57 Exporter::import
 49 main::check_file
 39 main::minusf_nocase
    (etc.)
```

Simple Coverage Analyzer

```
package Devel::Coverage;

sub DB::DB {
  my ($package, $file, $line) = caller();
  $files{$file} = 1;
  $covered{$file}[$line] = 1;
}

END {
  for my $file (keys %files) {
    my $array = \@{"::_<$file"};
    my ($executable, $covered) = (0, 0);
    for my $line (1 .. $#$array) {
      next if $array->[$line] == 0;
      $executable += 1;
      $covered += $covered{$file}[$line];
    }
    printf STDERR "%4d/%4d (%3.0f%%) covered in %s.\n",
      $covered, $executable, 100*$covered/$executable, $file
         unless $executable == 0;
  }
}
```

- In numeric context, `@{"::_<foo"}` elements are special
- They are equal to zero only when the line is not executable

```
10/  31 ( 32%) covered in /usr/local/lib/perl5/5.6.0/Exporter.
10/  70 ( 14%) covered in /usr/local/lib/perl5/5.6.0/Getopt/St
 8/  12 ( 67%) covered in /tmp/Devel/Coverage.pm.
60/  74 ( 81%) covered in ./MAKE_SLIDES.
```

Big Technique #6: Tokenizing

- *Tokens* are the basic syntactically meaningful portions of an input.
- For example, in

```
print 12+$var;
```

- The tokens are `print`, `12`, `+`, `$`, `var`, and `;`
- Individual characters are not generally meaningful.
- *Tokenizing* is the act of converting a character stream into a token stream.
- Also called *lexing*

Tokenizing

- In C, you use programs like `lex` to convert a description of the legal tokens into a tokenizer program.
- Or you write a program to read the input character-by-character and run a state machine
- That is not very Perl-like.
- It is also not very efficient.

Tokenizing

- A regex is *already* a program for reading data character-by-character and running a state machine
- Let’s write a lexer for a calculator. It has the following tokens:
  - `+`, `-`, `*`, `/`, `^`, `**`, `(`, `)`, `=`
  - `:=`
  - Variable names: `Value2`, for example
  - Numbers with optional decimal points and scientific notation
  - Whitespace will be ignored except where it separates tokens

Tokenizing

- Our trick:

```
split /(a+)/, $string
```

- This breaks `$string` into pieces which alternate between
  - Strings of a’s
  - The other stuff that was between the a’s
- Note special `split` meaning of `(`capturing parentheses`)`.

Tokenizing

- The tokenizer:

```
sub tokens {
  my @tokens =
    split m{(
             \*\* | :=  # ** or := operator
            |
             [-+*/^()=]  # some other operator
            |
             [A-Za-z]\w+ # Identifier
            |
             \d*\.\d+(?:[Ee]\d+)?  # Decimal number
            |
             \d+         # Integer
            )}x, shift();
  grep /\S/, @tokens;
}
```

- Easy to understand and to change, efficient, predictable.
- Behaves very much like similar `lex`-generated parsers

Tokenizing

- We can get rid of that `grep`:

```
sub tokens {
    split m{(
             \*\* | :=  # ** or := operator
            |
             [-+*/^()=]  # some other operator
            |
             [A-Za-z]\w+ # Identifier
            |
             \d*\.\d+(?:[Ee]\d+)?  # Decimal number
            |
             \d+         # Integer
            )
            |
            \s+
           }x, shift();
}
```

- (Thanks to Andy Wardley.)

Exportation (Inheritable Method)

- This exporter can be inherited by subclasses of `Rings`:

```
package Rings;
use Carp;

%exports = map {$_ => 1} qw(Narya Nenya Vilya);

sub import {
  my $caller = caller;
  my $package = shift;
    my $exported = \%{$package . '::exports'};
  for my $name (@_) {
      unless ($exported->{$name}) {
      croak("Module $package does not export &$name; aborting"
    }
      *{$caller . '::' . $name} = \&{$package . '::' . $name};
  }
}
```

Aliasing

```
my $exported = \%{$me . '::exports'};
```

```
... $exported->{$name} ...
```

- That worked well enough, but here's a better trick

```
local *exported = \%{$me . '::exports'};
```

- Now `%exported` *is* the hash.

```
... $exported{$name} ...
```

- You want the `local` so the change is confined to `import`
- You can't `my` a glob.

Aliasing

This is how Sarathy's clever `Alias` module works.

A typical object:

```
{ SALARY => 45_000, Children => ['Ishmael', 'Isaac'] }
```

A typical method:

```
sub method {
  my $self = attr shift;        # Alias::attr
  $SALARY *= 1.06;              # Raise salary 6%
  print "You have lovely children, named @Children.\n";
  pop @Children;                # Pay the price for that 6%
}
```

Another Tied Hash: `%!`

- Perl magic `$!` variable reflects the operating system error status
- Example of use:

```
unless (open FH, $filename) {
  if ($! == EACCES) {
    # Permission denied...
  } elsif ($! == ENOENT) {
    # No such file...
  } elsif ($! == ENOTDIR) {
    # Some part of the path is not a directory...
  } elsif ...
  }
}
```

- This doesn't work---where did `EACCESS` etc. come from?
- Solution 1: Import lots and lots of compile-time constants. (Blecch.)
- Solution 2: Use `%!` instead: (5.005 and later.)

```
unless (open FH, $filename) {
  if ($!{EACCES}) {
    # Permission denied...
  } elsif ($!{ENOENT}) {
    # No such file...
  } elsif ($!{ENOTDIR}) {
    # Some part of the path is not a directory...
  } elsif ...
  }
}
```

- When Perl saw you use `%!`, it loaded the `Errno` module and tied `%!` into it.
- `FETCH` method checks the value of `$!`.

`%!` Implementation

```
package Errno;

sub ENOENT () { 2 }
sub EACCES () { 13 }
sub ENOTDIR () { 20 }
# ... many more ...

sub TIEHASH { bless [] }                # Dummy object

sub FETCH {
  my ($self, $errname) = @_;
  return $! == &$errname;
}

sub STORE {
  croak("ERRNO hash is read only!");
}
```

- This was invented by Tom Christiansen and implemented by Graham Barr.

Bizarre Tricks

- A fruitful source of ideas is to ask:

  ‘‘What can I tie today?’’

- Then if you get an answer, you learn something new and interesting.
- For example: ‘‘I know! Let’s tie `$_`!’’

Bizarre `tie` Tricks: `no underscore`

- Theory: People find implicit use of `$_` confusing
- Sometimes, it’s a genuine error, as with

```
$z = s/x/y/g;                # Should be =~
```

- So let’s forbid it.

```
no underscore;              # Forbids use of $_

$z = s/x/y/g;               # Forbidden
print HANDLE;               # Forbidden
chop;                       # Forbidden
-x;                         # Forbidden
```

- This was invented by Tom Christiansen

`no underscore`

```
package underscore;
use Carp;

sub TIESCALAR {
    my $class = shift;
    my $dummy;
    return bless \$dummy => $class;
}

sub FETCH { croak "Read access to \$_ forbidden"  }
sub STORE { croak "Write access to \$_ forbidden" }

sub unimport { tie $_ => __PACKAGE__ }
sub import { untie $_ }

1;
```

`Import.pm` Module

- Idea: Method inheritance via `@ISA` is nice
- Wouldn’t it be nice to inherit regular functions also?
- We will emulate it with `AUTOLOAD`

```
sub AUTOLOAD {
  my $code = get_code($AUTOLOAD);
  goto &$code if $code;
  die "Undefined subroutine $AUTOLOAD called";
}

sub get_code {
  my ($fullname) = @_;
  return \&$fullname if defined &$fullname;
  my($pkg, $sub) = ($fullname =~ /(.*)::(.*)/);
  for my $parent (@{$pkg . '::ISA'}) {
    my $code = get_code(join '::', $parent, $sub);
    return $code if defined $code;
  }
  return;
}
```

- This was invented by Philip Gwyn

Build Your Own `map`

- `map` and `grep` are great.
- Wouldn't it be nice to make some new, similar operators?
- Example:

```
$n = reduce { $a + $b } 1, 4, 2, 8, 5, 7
```

(Yields the sum, 27)

```
$n = reduce { $a * $b } 1, 4, 2, 8, 5, 7
```

(Yields the product, 2240)

```
$n = reduce { $a > $b ? $a : $b } 1, 4, 2, 8, 5, 7
```

(Yields the max, 8)

```
$n = reduce { [@$a, $b] } [], (1, 4, 2, 8, 5, 7)
```

(Yields a list, [1,4,2,8,5,7])

`reduce`

```
sub reduce (&$@) {
  my $code = shift;
  local $a = shift;

  for (@_) {
    local $b = $_;
    $a = &$code;
  }

  $a;
}
```

- `(&$@)`?!
- `local`?!
- Why `$a` and `$b`?

reduce

- Here’s a fine, fine trick.
- Let’s write a `reduce` call to ask if a list contains all positive numbers.

```
reduce { $a && $b > 0 } "yes", @list;
```

- If you apply this to the list `(0 .. 1000000)`, it goes all way to the end
- Solution:

```
reduce { $a && $b > 0 || ($a=undef, last) } "yes", @list;
```

- `last`?!
- Yes! `last` is dynamically scoped!

combine

```
@list1 = (1,2,3,4,5);
@list2 = (2,3,5,7,11);
@result = combine { $a + $b } @list1, @list2;
```

`@result` is `(3,5,8,11,16)`

```
sub combine (&\@\@) {
  my ($code, $ar1, $ar2) = @_;
  my @result;

  while (@$ar1 && @$ar2) {
    local $a = shift @$ar1;
    local $b = shift @$ar2;
    push @result, &$code;
  }

  @result;
}
```

Matching Many Patterns at Once

```
@state_abbr = qw(AK AL AR AZ CA ... WV WY);

@state_pat = (
  'Alaska',
  'Alabama',
  'Arkansas',
  'Ariz(?:\.|ona)?',
  'Cal(?:\.|if(?:\.|ornia)?)?',
  ...
  'W(?:est|\.)?\s*V(?:irginia|\.)?',
  'Wyo(?:\.|ming)?',
);
```

- Given `$input`, does it match a state? Which one?

Matching Many Patterns at Once

- The wrong way:

```
for ($i=0; $i < @state_pat; $i++) {
  return $state_abbr[$i]
    if $input =~ /$state_pat[$i]/;
}
return;
```

Matching Many Patterns at Once

- A better way:

```
$pat = join '|', map "($_)", @state_pat;
```

- `$pat` now looks like:

```
(Alaska)|(Alabama)|...|(Wyo(?:\.|ming)?)
```

- Now use:

```
my @matchlist;
if (@matchlist = ($input =~ /$pat/o)
  my $i = 0;
  ++$i until defined $matchlist[$i];
  return $state_abbr[$i];
} else {
  return;
}
```

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- Caution: Important to use `(?:...)` instead of `(...)` in subpatterns.

Quick Return with Warning

```
unless (open LOG, ">> $LOGFILE") {
  warn "Couldn't append to $LOGFILE: $!";
  return;
}
```

- This is a very common locution.

- Perhaps you might prefer this:

```
return warn "Couldn't append to $LOGFILE: $!"
  unless open LOG, ">> $LOGFILE";
```

- That returns 1 on an open failure---perhaps not what you want.

```
return !warn "Couldn't append to $LOGFILE: $!"
  unless open LOG, ">> $LOGFILE";
```