Lecture 6

Shell Part II:
sh, bash, ksh

Parsing and Quoting

How the Shell Parses

- Part 1: Read the command:
  - Read one or more lines a needed
  - Separate into *tokens* using space/tabs
  - Form commands based on token types
- Part 2: Evaluate a command:
  - Expand word tokens (command substitution, parameter expansion)
  - ***Split words into fields***
  - Setup redirections, environment
  - Run command with arguments

Useful Program for Testing

/ftproot/okeefe/215/showargs.c

```
#include <stdio.h>
int main(int argc, char *argv[])
{
  int i;
  for (i=0; i < argc; i++) {
    printf("Arg %d: %s\n", i, argv[i]);
  }
  return(0);
}
```

Shell Comments

- Comments begin with an unquoted **#**
- Comments end at the end of the line
- Comments can begin whenever a token begins
- Examples

```
# This is a comment
# and so is this
grep foo bar # this is a comment
grep foo bar# this is not a comment
```

Special Characters

- The shell processes the following characters specially unless quoted:

  `| & ( ) < > ; " ' $ ` ` ***space tab newline***

- The following are special whenever patterns are processed:

  `* ? [ ]` (turn off with `set -o noglob`)

- The following are special at the beginning of a word:

  `# ~`

- The following are special when processing assignments:

  `= [ ]`

Token Types

- The shell uses spaces and tabs to split the line or lines into the following types of tokens:
  - Control operators (|, ||)
  - Redirection operators (<, >, >>)
  - Reserved words (while, if)
  - Assignment tokens (foo=bar)
  - Word tokens (everything else)

Operator Tokens

- Operator tokens are recognized everywhere unless quoted. Spaces are optional before and after operator tokens.
- I/O Redirection Operators:

  `> >> >| >& < << <<- <&`

  - Each I/O operator can be immediately preceded by a single digit
- Control Operators:

  `| & ; ( ) || && ;;`

Shell Quoting

- Quoting causes characters to loose special meaning.
- \ Unless quoted, \ causes next character to be quoted. In front of new-line causes lines to be joined.
- '…' Literal quotes. Cannot contain '
- "…" Removes special meaning of all characters except **$**, **"**, \ and `. The \ is only special before one of these characters and new-line.

Quoting Examples

```
$ cat file*
a
b
```

```
$ cat "file*"
cat: file* not found
```

```
$ cat file1 > /dev/null
$ cat file1 ">" /dev/null
a
cat: >: cannot open
```

```
FILES="file1 file2"
$ cat "$FILES"
cat: file1 file2 not found
```

Simple Commands

- A simple command consists of three types of tokens:
  - Assignments (must come first)
  - Command word tokens (name and args)
  - Redirections: *redirection-op* + *word-op*
  - The first token must not be a reserved word
  - Command terminated by new-line or **;**
- Example:
  - ```
    foo=bar z=`date`
    print $HOME
    x=foobar > q$$ $xyz z=3
    ```
    ```

Word Splitting

- **After parameter expansion**, **command substitution**, and arithmetic expansion, the characters that are generated as a result of these expansions (if not inside double quotes) are checked for split characters
- Default split character is *space* or *tab*
- Split characters are defined by the value of the **`IFS`** variable (**`IFS=""`** disables)

Word Splitting Examples

```
FILES="file1 file2"
cat $FILES
a
b

IFS=
cat $FILES
cat: file1 file2: cannot open
```

```
IFS=x v=exit
print exit $v "$v"
exit e it exit
```

Pathname Expansion

- After word splitting, each field that contains pattern characters is replaced by the pathnames that match
- Quoting prevents expansion
- **`set -o noglob`** disables
  - Not in original Bourne shell, but in POSIX

Parsing Example

```
DATE=`date` echo $foo > \
      /dev/null
```

```
DATE=`date`   echo   $foo   > /dev/null
```

assignment *word* *param* *redirection*

```
echo   hello there
```

→ */dev/null*

```
/bin/echo   hello   there
```

→ */dev/null*

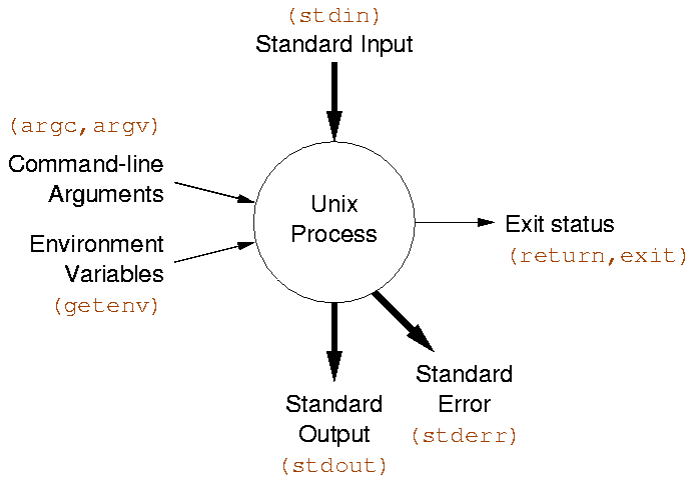
PATH expansion *split by IFS*

The eval built-in

- **`eval` *`arg`* …**
  - Causes all the tokenizing and expansions to be performed again

Input/Output Shell Features

- Standard input, output, error
  - Redirection
  - Here documents
  - Pipelines
  - Command substitution
- Exit status
  - `$?`
  - `&&`, `||`, `if`, `while`
- Environment
  - `export`, variables
- Arguments
  - Command substitution
  - Variables
  - Wildcards



Power of the Shell

- The shell is a language that lets you use programs as you would use procedures in other languages
  - Called with command line arguments
  - If used in if, while statements programs behave like functions returning a boolean value
    - /bin/true: Program that just does exit(0)
    - /bin/false: Program that just does exit(1)
  - If used in command substitution, programs behave like functions returning a string
  - Environment behaves like global variables

test Summary

- **String based tests**

`-z string`	Length of string is 0
`-n string`	Length of string is not 0
`string1 = string2`	Strings are identical
`string1 != string2`	Strings differ
`string`	String is not NULL

- **Numeric tests**

`int1 –eq int2`	First int equal to second
`int1 –ne int2`	First int not equal to second
`-gt`, `-ge`, `-lt`, `-le`	greater, greater/equal, less, less/equal

- **File tests**

`-r file`	File exists and is readable
`-w file`	File exists and is writable
`-f file`	File is regular file
`-d file`	File is directory
`-s file`	file exists and is not empty

- **Logic**

`!`	Negate result of expression
`-a`, `-o`	and operator, or operator
`( expr )`	groups an expression

Example

```
#!/bin/sh

if test -f /tmp/stuff && \
   [ `wc –l < /tmp/stuff` -gt 10 ]
then
      echo "The file has more than 10 lines"
else
      echo "The file is nonexistent or small"
fi
```

Arithmetic

- No arithmetic built in to **`/bin/sh`**
- Use external command **`/bin/expr`**
- **`expr expression`**
  - Evaluates expression and sends the result to standard output
  - Yields a numeric or string result

```
expr 4 "*" 12
expr \( 4 + 3 \) \* 2
```

for loops

- Different than C:

```
for var in list
   do
   command
   done
```

- Typically used with positional params or a list of files:

```
sum=0
   for var in "$@"
   do
    sum=`expr $sum + $var`
   done

for file in *.c ; do echo "We have $file"
   done
```

Case statement

- Like a C switch statement for strings:
  - ```
    case $var in
      opt1) command1
            command2
            ;;
      opt2) command
            ;;
      *)    command
            ;;
    esac
    ```
- ***** is a catch all condition
    ```

Case Example

```
#!/bin/sh

echo "Say something."
while true
do
    read INPUT_STRING
    case $INPUT_STRING in
        hello)
            echo "Hello there."
            ;;
        bye)
            echo "See ya later."
            ;;
        *)
            echo "I'm sorry?"
            ;;
    esac
done
echo "Take care."
```

Case Options

- **opt** can be a shell pattern, or a list of shell patterns delimited by **|**
- Example:

```
case $name in
    *[0-9]*)
        echo "That doesn't seem like a name."
        ;;
    J*|K*)
        echo "Your name starts with J or K, cool."
        ;;
    *)
        echo "You're not special."
        ;;
esac
```

Types of Commands

All behave the same way

- Programs
  - Most that are part of the OS in /bin
- Built-in commands
- Functions
- Aliases

Built-in Commands

- Built-in commands are internal to the shell and do not create a separate process. Commands are built-in because:
  - They are intrinsic to the language (**exit**)
  - They produce side effects on the process (**cd**)
  - They perform much better
    - No fork/exec

Important Built-in Commands

exec	:	replaces shell with program
cd	:	change working directory
shift	:	rearrange positional parameters
(un)set	:	set positional parameters
wait	:	wait for background proc. to exit
umask	:	change default file permissions
exit	:	quit the shell
eval	:	parse and execute string
time	:	run command and print times
export	:	put variable into environment
trap	:	set signal handlers

Important Built-in Commands

continue : continue in loop

break : break in loop

return : return from function

: : true

. : read file of commands into current shell; like **`#include`**

Reading Lines

- **read** is used to read a line from a file and to store the result into shell variables
  - **read –r** prevents special processing
  - Uses **IFS** to split into words
  - If no variable specified, uses **REPLY**

```
read
read –r NAME
read FIRSTNAME LASTNAME
```

trap command

- **trap** specifies command that should be executed when the shell receives a signal of a particular value.
- **`trap [ [`***command***`] {`***signal***`}+]`**
  - If ***command*** is omitted, signals are ignored
- Especially useful for cleaning up temporary files

```
trap 'echo "please, dont interrupt!"' SIGINT

trap 'rm /tmp/tmpfile' EXIT
```

Functions

Functions are similar to scripts and other commands except that they can produce side effects in the callers script. The positional parameters are saved and restored when invoking a function. Variables are shared between caller and callee.

Syntax:

```
name ()
{
    commands
}
```

Aliases

- Like macros (#define in C)
- Shorter to define than functions, but more limited
- Not recommended for scripts
- Example:

```
alias rm='rm –i'
```

Search Rules

- Special built-ins
- Functions
  - *command* bypasses search for functions
- Built-ins not associated with PATH
- PATH search
- Built-ins associated with PATH
- Executable images

Script Examples

- Rename files to lower case
- Strip CR from files
- Emit HTML for directory contents

Rename files

```
#!/bin/sh

for file in *
do
        lfile=`echo $file | tr A-Z a-z`
        if [ $file != $lfile ]
        then
                mv $file $lfile
        fi
done
```

Remove DOS Carriage Returns

```
#!/bin/sh

TMPFILE=/tmp/file$$

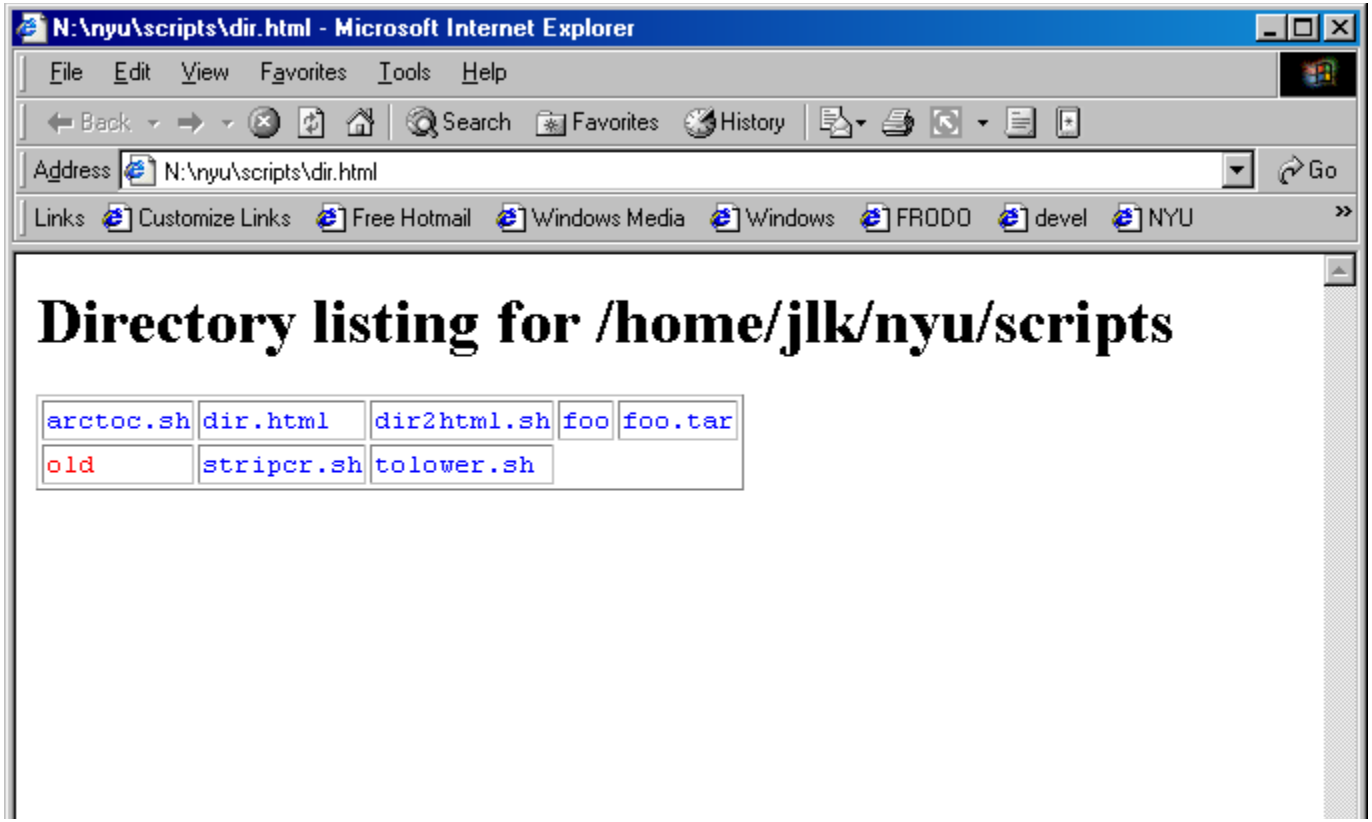
if [ "$1" = "" ]
then
        tr -d '\r'
        exit 0
fi

trap 'rm -f $TMPFILE' EXIT

for file in "$@"
do
        if tr -d '\r' < $file > $TMPFILE
        then
                mv $TMPFILE $file
        fi
done
```

Generate HTML

```
$ dir2html.sh > dir.html
```



The Script

```
#!/bin/sh

if test –n "$1"
then
  cd "$1"
fi
cat <<HUP
 <html>
 <h1> Directory listing for $PWD </h1>
 <table border=1>
 <tr>
HUP
num=0  # global variable counting file number
for file in *
do
    genhtml $file   # this function is on next
page
done
cat <<HUP
 </tr>
 </table>
 </html>
```

Funciton genhtml

```
genhtml()
{
    file=$1
    echo "<td><tt>"
    if [ -f $file ]
    then    echo "<font color=blue>$file</font>"
    elif [ -d $file ]
    then    echo "<font color=red>$file</font>"
    else    echo "$file"
    fi
    echo "</tt></td>"
    # Check if this is the end of the row
    num=`expr $num + 1`
    if [ $num -gt 4 ]
    then
        echo "</tr><tr>"
        num=0
    fi
}
```

Korn Shell / bash Features

Command Substitution Syntax

- Better syntax with $(*command*)
  - Allows nesting
  - **`x=$(cat $(generate_file_list))`**
- Backward compatible with ` … ` notation

Expressions

- Expressions are built-in with the **`[[ ]]`** operator

`if [[ $var = "" ]] …`

- Gets around parsing issues when using **/bin/test,** allows checking strings against *patterns*
- Operations:
  - *string* **`==`** *pattern*
  - *string* **`!=`** *pattern*
  - *string1* **`<`** *string2*
  - *file1* **`-nt`** *file2*
  - *file1* **`-ot`** *file2*
  - *file1* **`-ef`** *file2*
  - **`&&`, `||`**
- Patterns:
  - Can be used to do string matching

```
if [[ $foo = *a* ]]
if [[ $foo = [abc]* ]]
```

Additonal Parameter Expansion

- ${*#param*} – Length of *param*
- ${*param#pattern*} – Left strip min *pattern*
- ${*param##pattern*} – Left strip max *pattern*
- ${*param%pattern*} – Right strip min *pattern*
- ${*param%%pattern*} – Right strip max *pattern*
- ${*param-value*} – Default *value* if *param* not set

Variables

- Variables can be arrays
  - `foo[3]=test`
  - `echo ${foo[3]}`
- Indexed by number
- **`${#arr}`** is length of the array
- Multiple array elements can be set at once:
  - `set –A foo a b c d`
  - `echo ${foo[1]}`

Set command can also be used for positional params: `set a b c d; print $2`

Functions

- Alternative function syntax:

```
function name {
    commands
}
```

- Allows for local variables (with `typeset`)
- `$0` is set to the name of the function

Additional Features

- Built-in arithmetic: Using $((*expression*))
  – e.g., **`print $(( 1 + 1 * 8 / x ))`**
- Tilde file expansion

~	$HOME
~user	home directory of user
~+	$PWD
~-	$OLDPWD

Printing (ksh only)

- Built-in **print** command to replace echo
- Not subject to variations in echo
- Much faster
- Allows options:

  -u# print to specific file descriptor

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Variable Attributes

- By default attributes hold strings of unlimited length
- Attributes can be set with typeset:
  - readonly (-r) – cannot be changed
  - export (-x) – value will be exported to env
  - upper (-u) – letters will be converted to upper case
  - lower (-l) – letters will be converted to lower case
  - ljust (-L *width*) – left justify to given width
  - rjust (-R *width*) – right justify to given width
  - zfill (-Z *width*) – justify, fill with leading zeros
  - integer (-I [*base*]) – value stored as integer
  - float (-E [*prec*]) – value stored as C double
  - nameref (-n) – a name reference

Name References

- A name reference is a type of variable that references another variable.
- **`nameref`** is an alias for **`typeset -n`**
  - Example:

```
user1="jeff"
user2="adam"
typeset –n name="user1"
print $name
jeff
```

New Parameter Expansion

- ${*param*/*pattern*/*str*} – Replace first pattern with *str*
- ${*param*//*pattern*/*str*} – Replace all patterns with *str*
- ${*param*:*offset*:*len*} – Substring

Patterns Extended

- Additional pattern types so that shell patterns are equally expressive as regular expressions
- Used for:
  - file expansion
  - `[[ ]]`
  - case statements
  - parameter expansion

Patterns	*Regular Expressions*
`?`	`.`
`*`	`.*`
`[...]`	`[...]`
`[!...]`	`[^...]`
`?(...)`	`(...)?`
`*(...)`	`(...)*`
`+(...)`	`(...)+`
`@(...)`	`(...)`
`!(...)`	
`a|b`	`a|b`
`a&b`	
`{n}(...)`	`(...){n}`
`{m,n}(...)`	`(...){m,n}`
`\d`	`\d`

ANSI C Quoting

- **`$'…'`** Uses C escape sequences

`$'\t'  $'Hello\nthere'`

- **printf** added that supports C like printing:

```
printf "You have %d apples" $x
```

- Extensions
  - %b – ANSI escape sequences
  - %q – Quote argument for reinput
  - \E – Escape character (033)
  - %P – convert ERE to shell pattern
  - %H – convert using HTML conventions
  - %T – date conversions using date formats

Associative Arrays

- Arrays can be indexed by string, like awk
- Declared with **`typeset -A`**
- Set: **`name["foo"]="bar"`**
- Reference **`${name["foo"]}`**
- Subscripts: **`${!name[@]}`**

Coprocesses

- **`|&`** operator supports a simple form of concurrent processing
- **`cmd |&`**

  cmd runs as a background process whose standard input and output channels are connected to the original parent shell via a two way pipe.
- Can read and write from process with
  - **`read -p`**
  - **`print -p`**
- Note that **echo** couldn't be used. Why?

C Expressions

- We have already seen built-in expressions with the **`[[ ]]`** operator:
  - **`[[ $var = *foo* ]] && print "contains foo"`**
- New operator **`(( ))`** for C-like numeric expressions:
  - **`(( x > 10 )) && print "x=$x, greater than 10"`**
  - **`(( x ++ ))`**
  - Note variables don't have to be used with **`$`** inside parens
- Value of **`(( ))`** expression can be used with **`$(( ))`**
  - **`y=$(( x + 1 ))`**
  - **`print $(( x * y - sin(y) ))`**

Compound Variables

- Variables can contain subfields (like structures or classes)
- Syntax: variable name containing **.**
- Example:

```
cust=(name=Jeff zip=10003)
cust.state=NY
print ${cust.name}
print ${!cust.*}
```

New for loop syntax

- Regular syntax:

```
for var in list
do
   …
done
```

- Additional syntax like C:

```
for (( initialization; condition; increment ))
do
   …
done
```

- Example: `for (( i=0; i < $VAR; i++))`

Example: Word Count

```
#!/home/unixtool/bin/ksh

integer l=0 w=0 c=0
while read –r LINE
do
        (( l++ ))
        set -- $LINE
        (( w += $# ))
        (( c += ${#LINE}+1 ))
done < $1

print "$l lines, $w words, $c characters"
```

Example: Word Count

```
integer l=0 w=0 c=0
while read –r LINE
do
        (( l++ ))
        set -- $LINE
        (( w += $# ))
        (( c += ${#LINE}+1 ))
done < $1

print "$l lines, $w words, $c characters"
```

- **`integer`** tag indicates variables will be used as integers
- **`while`** loop is a command, so redirection works

Example: Word Count

```
integer l=0 w=0 c=0
while read –r LINE
do
        (( l++ ))
        set -- $LINE
        (( w += $# ))
        (( c += ${#LINE}+1 ))
done < $1

print "$l lines, $w words, $c characters"
```

- **`set -- $LINE`** turns LINE into positional parameters ($1, …), splitting up the value with IFS
- **`$#`** is the number of positional parameters

Example: Word Count

```
integer l=0 w=0 c=0
while read –r LINE
do
        (( l++ ))
        set -- $LINE
        (( w += $# ))
        (( c += ${#LINE}+1 ))
done < $1

print "$l lines, $w words, $c characters"
```

- **${#LINE}** returns the length of the value of LINE
- We add 1 because the newline character is not part of LINE

Example: Spell a Phone Number

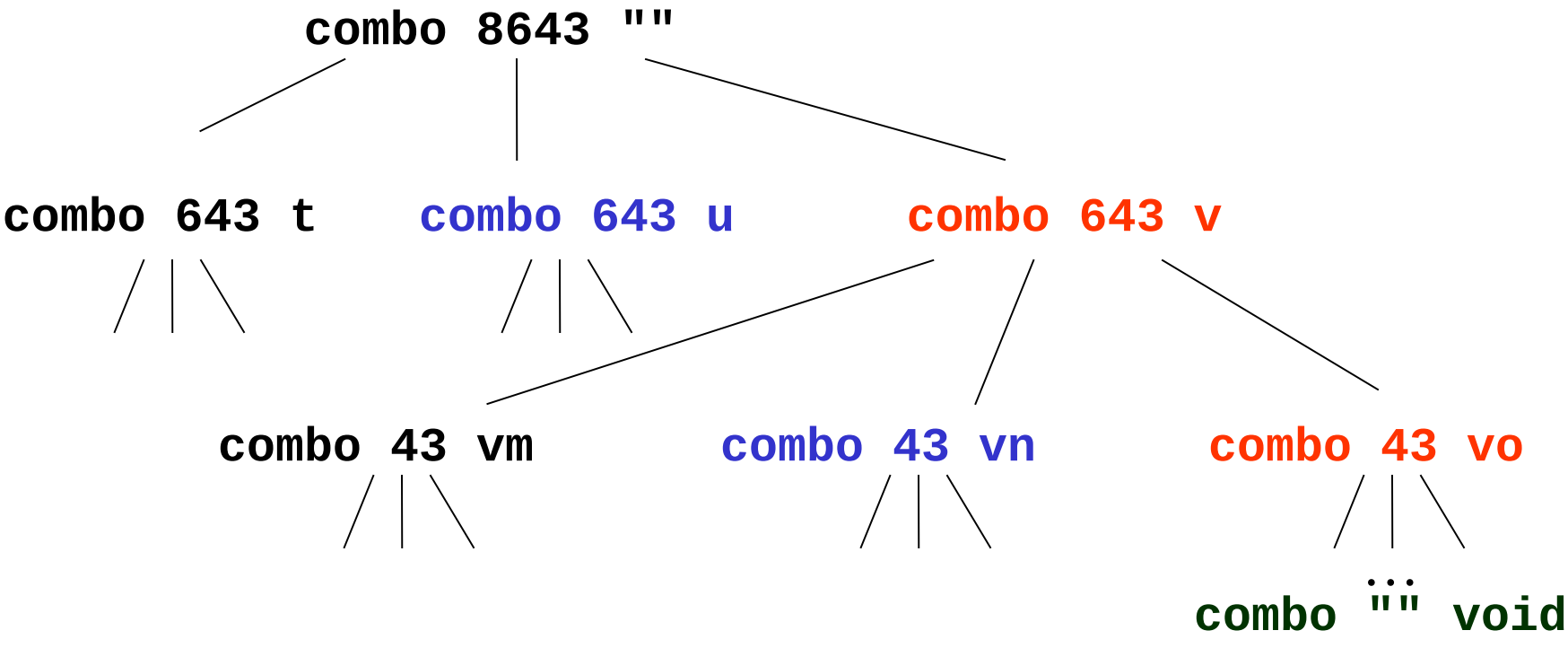
Given a number, finds possible words that the number spells on a telephone.

Example:

```
$ phonespell 8643
void
```

Algorithm

- Create function **combo** that prints all combinations of words. Check those against the dictionary.
- function **combo** is *recursive*:
  - Pass in part of number, part of word spelled



Example: Spell a Phone Number

```
function combo
{
        typeset num=$1 word=$2
        if      [[ $num = '' ]]
        then    print $word
        else    typeset -L1 digit=$num
                for letter in ${get_letter[digit]}
                do      combo "${num#?}" "$word$letter"
                done
        fi
}
```

- functions defined in ksh take arguments as positional parameters, like commands
- **`typeset`** makes a variable local

Example: Spell a Phone Number

```
function combo
{
        typeset num=$1 word=$2
        if      [[ $num = '' ]]
        then    print $word
        else    typeset -L1 digit=$num
                for letter in ${get_letter[digit]}
                do      combo "${num#?}" "$word$letter"
                done
        fi
}
```

- End of recursion: If number is empty, just print the given word. Should end up happening for every combination

Example: Spell a Phone Number

```
function combo
{
        typeset num=$1 word=$2
        if      [[ $num = '' ]]
        then    print $word
        else    typeset -L1 digit=$num
                for letter in ${get_letter[digit]}
                do      combo "${num#?}" "$word$letter"
                done
        fi
}
```

- Extract leftmost digit from **num**

Example: Spell a Phone Number

```
function combo
{
        typeset num=$1 word=$2
        if      [[ $num = '' ]]
        then    print $word
        else    typeset -L1 digit=$num
                for letter in ${get_letter[digit]}
                do      combo "${num#?}" "$word$letter"
                done
        fi
}
```

- **`for`** loop goes through all letters that correspond to the number (stored in **`get_letter`** array, shown next slide)
- Recursively calls itself for each letter, taking off one character from the left (using the **#** operator with pattern **?**)

Spell a Phone Number (cont')

```
set -A get_letter o i "a b c" "d e f" "g h i" "j k l" \
        "m n o" "p r s" "t u v" "w x y"
```

```
# method 1
combo $1 | comm -12 /usr/dict/words -
```

```
# method 2
trap 'rm -f /tmp/full$$' EXIT
combo $1  > /tmp/full$$
spell < /tmp/full$$ | comm -13 - /tmp/full$$
```

- **set –A *arrayname value value ...***
  - sets elements of an array all at once

Spell a Phone Number (cont’)

```
set -A get_letter o i "a b c" "d e f" "g h i" "j k l" \
        "m n o" "p r s" "t u v" "w x y"
```

```
# method 1
combo $1 | comm -12 /usr/dict/words -
```

```
# method 2
trap 'rm -f /tmp/full$$' EXIT
combo $1  > /tmp/full$$
spell < /tmp/full$$ | comm -13 - /tmp/full$$
```

- Call function **combo** with first argument, pipe to **comm**
  - suppress fields 1 and 2 (show only matching lines)
  - **combo** emits sorted lines, and dictionary is sorted so **comm** works well

Spell a Phone Number (cont’)

```
set -A get_letter o i "a b c" "d e f" "g h i" "j k l" \
        "m n o" "p r s" "t u v" "w x y"

# method 1
combo $1 | comm -12 /usr/dict/words -
```

```
# method 2
trap 'rm -f /tmp/full$$' EXIT
combo $1  > /tmp/full$$
spell < /tmp/full$$ | comm -13 - /tmp/full$$
```

- Another method: use **`spell`** command
  - Create temporary file storing combos
  - Run through spell, generating list of misspelled words
  - Pipe to **`comm`**, suppressing fields 1 and 3 (show correct words)

Example: Mortgage Calculator

```
float rate=$1 principle=$2 payment
integer months years=$3

[[ $1 ]] || read -r 'rate?rate in per cent: '
[[ $2 ]] || read -r 'principle?principle: '
[[ $3 ]] || read -r 'years?years to amoritization: '

print "\n\n\tprinciple\t$principle"
print "\trate\t\t$rate"
print "\tamortization\t$years"
```

```
(( months = years*12 ))
(( rate /= 1200. ))
(( payment = (principle*rate)/(1.-pow(1.+rate,-months)) ))
```

- Declare variables
- Read in unspecified inputs

Example: Mortgage Calculator

```
float rate=$1 principle=$2 payment
integer months years=$3

[[ $1 ]] || read -r 'rate?rate in per cent: '
[[ $2 ]] || read -r 'principle?principle: '
[[ $3 ]] || read -r 'years?years to amortization: '

print "\n\n\tprinciple\t$principle"
print "\trate\t\t$rate"
print "\tamortization\t$years"

(( months = years*12 ))
(( rate /= 1200. ))
(( payment = (principle*rate)/(1.-pow(1.+rate,-months)) ))
```

- Initialize values
- Uses built-in arithmetic (**pow**, floating point **/**)

Example: Mortgage Calculator

```
printf "\tmonthly payment\t%8.2f\n\n" "$payment"
print '\tYears   Balance'
print '\t======   =======' 
```

```
for    (( months=0; principle > 0; months++))
do     (( principle *= (1.+rate) ))
        (( principle -= payment ))
       if      (( ((months+1)%12) == 0 ))
       then    printf "\t%d\t%8.2f\n" months/12 "$principle"
       fi
done
```

- Print table header
  - Uses **printf** to format floating point number

Example: Mortgage Calculator

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       fi
done
```

- C-style for loop with numerical calculations

Documentation

- Web version of ***Learning the KornShell*** documents ksh93. Good for learning ksh.
- Glass documents ksh88 and bash
- UNIX in a Nutshell has a chapter that is a great ksh93 reference. Documents:
  - Bourne shell compatible features
  - ksh88 compatible features
  - ksh93 features