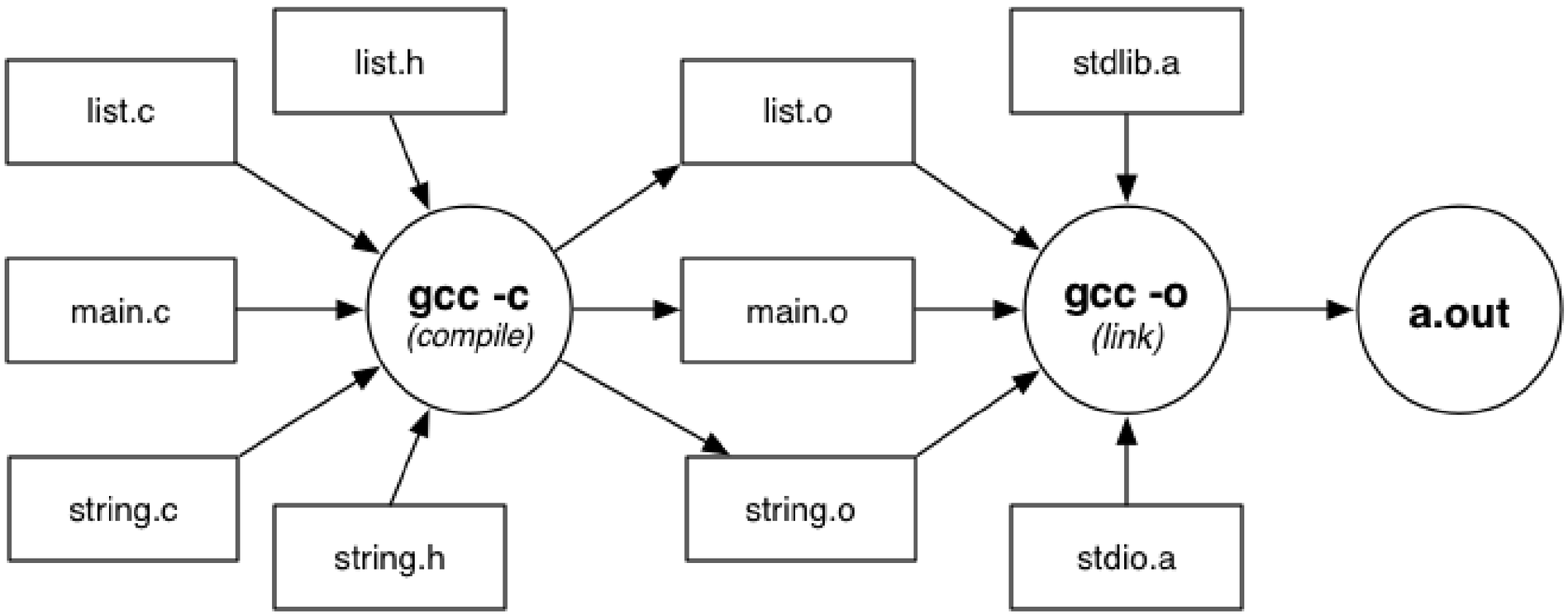
Compilation, Debugging and Makefiles

Computing 2 16x1

The C compiler (GCC)

- applies source-to-source transformation (pre-processor)
- compiles *source code* to produce *object files*
- links object files and *libraries* to produce *executables*



Compilation and Linking with GCC

- gcc –c list.c
  - Produces list.o from list.c and list.h
- gcc –c string.c
  - Produces string.o from string.c and string.h
- gcc –c main.c
  - Produces main.o from main.c, list.h, string.h
- gcc –o a.out main.o string.o list.o
  - Links main.o, string.o, list.o and libraries to create an executable called a.out

Debugging

- Initial versions of programs always have errors
- Symptoms of errors
  - Program quits with fatal error (eg segfault)
  - Program runs forever (infinite loop)
  - Program does not produce expected results
- Errors can be caused by
  - Misunderstanding programming language constructs
  - Misunderstanding the problem
  - Incorrect logic
  - Carelessness (uninitialized, off-by-one, pointers)

Debugging

- Debugging: process of
  - Finding the location/s of incorrect code
  - Fixing incorrect code that causes error
- Debuggers: software tools that
  - Assist in the process of debugging
    - By allowing detailed observation of execution state
- Critical part of debugging
  - Narrowing focus to small region of large code/state

Debugging

- Testing can help debugging
  - Test cases for boundary conditions (eg. Empty list)
  - Sequence of tests revealing
    - Trigger points .. ok before, fails after
    - Patterns of behaviour … eg. Always one more than expected
- Use deduction to identify/explain patterns.
- In general: run more tests before resorting to debugger

GDB: The GNU Debugger

- gdb provides facilities to
  - Control execution of program
    - Step by step execution, breakpoints
  - View intermediate state of program
    - Values stored in program variables
- Plain **gdb** uses a command-line interface
- ddd provides a GUI wrapper around gdb.

- Must be compiled with –gdwarf-2 option

Basic GDB Commands

- quit: quits from gdb
- help [CMD] : on-line help
- run ARGS: run the program
  - ARGS are whatever you normally use eg.
  - $ xyz < data
  - Would be run in gdb like
  - (gdb) run < data

Basic GDB Commands

- where: stack trace
  - Find which function the program was executing when it crashed.
  - Stack may also have references to system error-handling functions
- up [N]: move down the stack
  - Allows you to skip to scope of a particular function
- list [LINE]: show code
  - Displays five lines either side of current statement
- print EXPR: display expression values
  - EXPR may use (current values of) variables

GDB Execution commands

- break [FUNC|LINE] : set break-point
  - Stop execution and return control to gdb on entry to function FUNC or on reaching line LINE
- next: single step (over functions)
  - execute next statement
  - if the statement is a function call, execute the whole function
- step: single step (into functions)
  - Execute next statement
  - if statement is a function call, go to first statement in function body
- For more details see gdb’s on-line help

Exercise: Monitoring program Execution

- Use GDB to examine the execution of the following:
  - Iterative factorial function fac0.c
  - Recursive factorial function fac.c
  - Iterative list traversal List.c
- Do each of the following:
  - Set a breakpoint
  - Run the program with command line arguments
  - Check the stack
  - Display the values of variables
  - Continue execution after the breakpoint

Building Software Systems

- Software systems need to be built/rebuilt
  - During development phase (change,compile,test,repeat)
  - If distributed in source code form (assists portability)

- How can we easily build C program from
  - Multiple files and libraries
  - Re-compiling only what is necessary

MAKEFILES

- **Make** is a software configuration tool that
  - specifies dependencies between software components
  - controls compilation when source code is updated
  - produces "minimal required recompilation" on update
- In fact, it can be used for any task which involves
  - multiple inter-dependent files
  - need to produce some files from others

MAKEFILES…

- **make** is driven by dependencies given in a **Makefile**

- A *dependency* specifies

target : $source_1$ $source_2$ ...
  commands to build target from sources

- e.g.

```
eval: eval.o tokens.o stack1.o
  gcc -o eval eval.o tokens.o stack1.o
```

- Rule: *target* is rebuilt if older than any $source_i$

Example Makefile

```
game : main.o list.o string.o
  gcc -o game main.o list.o string.o -lm
main.o : main.c list.h string.h
  gcc -Wall -Werror -O -c main.c
list.o : list.c list.h
  gcc -Wall -Werror -O -c list.c
string.o : string.c
  gcc -Wall -Werror -O -c string.c
clean :
  rm -f *.o core
clobber : clean
  rm -f game
```

How Make Works

- The make command behaves as:
- make(target):

  Find makefile rule for the target

  for each S in Sources { make(S) }

  if (no sources OR any source is newer than target){

    perform Action to rebuild target

  }

Example Makefile Revisisted

```
CC = gcc
CFLAGS = -Wall -Werror -O
LDFLAGS = -lm
game : main.o list.o string.o
  $(CC) -o game main.o list.o string.o ($LDFLAGS)
main.o : main.c list.h string.h
  $(CC) $(CFLAGS) -c main.c
list.o : list.c list.h
  $(CC) $(CFLAGS) -c list.c

Etc…
```

Running Make

- To build the first target in the makefile just type
- **make**
- If make arguments are targets, build just those targets:
- **make world.o**
- **make clean**
- **make clobber**

- The -n option instructs make
  - to tell what it would do to create targets
  - but don't execute any of the commands