Welcome!

COMP2521 25T3
Data Structures and Algorithms

COMP2521 25T3
Introduction

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course introduction
tools of the trade

Course Goals

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to get you thinking like a *computer scientist*
not just a programmer

- know and understand *fundamental* data structures, algorithms
- reason about *applicability* + *effectiveness*
- analyse behaviour/correctness of programs

Assumed Knowledge

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We assume that you can:

- Produce a correct C program from a specification
- Use fundamental control structures
  (sequence, selection (`if`), iteration (`while`))
- Use fundamental C data types and data structures
  (`char`, `int`, `double`, arrays, `structs`, pointers, linked lists)

Acquired Knowledge

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In this course, you will learn:

- data structures: trees, graphs, hash tables, tries
- data structure/algorithm analysis: time/space complexity
- sorting and searching techniques
- graph algorithms

Acquired Skills

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By the end of this course, you should be able to:

- Implement solutions to a wider range of problems
- Analyse performance characteristics of algorithms
- Analyse performance characteristics of data structures
- Make decisions about appropriate data structures and algorithms

Course Staff

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Convenor	John Shepherd
Lecturer	Sim Mautner
Admins	Kevin Luxa, Ethan Brown and Ryan Berlee

Contact

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Website `https://webcms3.cse.unsw.edu.au/COMP2521/25T3/`

Email cs2521@cse.unsw.edu.au

Teaching/Assessment Methods

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Lectures
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Lectures

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Four hours of lectures per week

- Monday 14:00–16:00; Wednesday 11:00–13:00
  - In person in E19 Patricia O'Shane 104
  - Also livestreamed via YouTube
  - Link to livestream on the lectures page
  - Feel free to ask questions in the chat
  - Recordings will be on YouTube
- present a brief overview of theory
- demonstrate problem-solving methods
- give practical demonstrations

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Tutorials

Weekly one-hour tutorials

- tutorials start in week 1
  - run every week, except flex week
  - online classes are via Blackboard Collaborate
- tutorials clarify lecture material
- work through problems related to lecture topics
- questions available (usually) the week before
- answers available Friday evening

To get the best out of tutorials

- read and attempt the problems yourself beforehand
- don't keep quiet in tutorials... talk, discuss, ...
- ask if you don't understand something

Labs

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Each tutorial is followed by a two-hour lab class

- several exercises, mostly small implementation/analysis tasks
- aim to improve your coding and analysis skills
- give you experience applying algorithms and techniques
- done individually, unless specified
- submitted via `give`, before Monday ~~17:00~~ 09:00 the following week
- many labs have a handmarking component (see spec for details)
  - handmarking completed by showing your work to your tutor in the lab **within two weeks of the lab**
- worth 15% of your final mark, best 7 of 8 labs used to calculate the 15%

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Quizzes

Weekly quizzes

- on WebCMS
- questions about previous week's lectures
- different kinds of questions
  - multiple choice, multiple select, fill-in-the-blank...
- aim to test your knowledge and understanding of the theory
- done individually
- due Monday ~~17:00~~ 09:00 the following week
- can submit multiple times, only last submission is marked
- worth 10% of your final mark, best 7 of 8 quizzes used to calculate the 10%

Assignments

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Two assignments

- each worth 15% of your final mark
- give you experience applying algorithms to larger problems
- done individually
- help sessions will be available to assist with assignments
  - will be very busy in the last days before an assignment is due

Late Penalties

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Labs, quizzes and assignments all have the same late penalty

- UNSW standard late penalty
- **0.2%** of the maximum mark taken from your raw mark for each hour late
  - equivalent to 4.8% per day
- submissions later than 5 days not allowed (automatically enforced)

Sample Solutions and Marking

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Due to the UNSW standard late penalty allowing late submissions up to 5 days after the deadline, along with extensions for special consideration:

- sample solutions for labs will be released 12 days after the due date
- marks for labs will be released a week after the due date
- answers and marks for quizzes will be released 5 days after the due date
- sample solutions for assignments are not released
- marks for assignments are released in two parts
  - automarking will be released a week after the due date
  - handmarking (style, automarking adjustments) takes longer and will be released 2 weeks after the automarking

Final Exam

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- 3 hour in-person exam, during exam period
- Limited resources provided
- Two sections:
  - Theory - short-answer questions
  - Programming - programming questions
- To pass the exam hurdle, you must:
  - score at least 18/45 (40%) on the final exam
  - score at least 25% in the theory section of the exam
  - score at least 25% in the programming section of the exam

Special Consideration

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- Have you been impacted by unforeseen adverse circumstances?
- Has it affected your ability to complete coursework?
- You can apply for special consideration via myUNSW
- Find out how to apply here:
  `https://student.unsw.edu.au/special-consideration`

Assessment

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Summary:

15% labs
10% quizzes
15% assignment 1
15% assignment 2
45% final exam

Assessment

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To pass COMP2521, you must:

- score at least 50/100 overall
- pass the exam hurdle

Academic Integrity

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- Labs, quizzes and assignments must be entirely your own work
- Plagiarism will be checked for and penalised
- Plagiarism may result in suspension from UNSW
- Scholarship students may lose their scholarship
- International students may lose their visa
- Supplying your work to any other person may result in loss of all your marks for the lab/assignment

Academic Integrity

Generative AI Tools

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- Use of generative AI tools, e.g., GitHub Copilot, ChatGPT, with the intention of generating answers/solutions for assessment tasks is not permitted
- Use of generative AI tools for learning is permitted
  - You must still be critical of any response you get from these tools
- Generative AI tools have great potential to assist coders, but use of them requires good understanding of the language/system

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Resources

Additional Help

- Discourse forum
- Weekly consultations
  - Starting from week 2
  - Wednesday 1pm-2pm
  - In person (location to be confirmed)
  - For clarification of course content
- Help sessions
  - Starting from week 2
  - Schedule on course website
  - For help with labs and assignments

Resources

Additional Exercises

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- Attempt lecture excercises by yourself using the `starter` code provided
- Practice exercises by topic: here
- Extra lab exercises
- LeetCode/HackerRank problems for more practice: here

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Expectations

What we expect from you

- Check your email regularly
  - Announcements will be sent to your email
  - Your tutor will send you emails
  - Reminders of unsubmitted work will be sent to your email
- Read the spec before asking questions
  - Don't ask questions that are already answered in the spec
- Attempt to debug your program yourself before asking for help
  - Debugging may involve adding print statements or using gdb to check the state of the program at various points, or drawing diagrams to visualise the program's execution

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Expectations

What you can expect from us

- Regular announcements/updates
- Lecture slides released before lectures
- Minimal typos/mistakes in lecture slides
- Tutorial questions/lab exercises released on time (by the weekend before)
- Assignments released on time
- Assignments marked on time

Advice

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- Keep up with lectures
  Labs and quizzes require you to know content from recent lectures
- Attend tutorials, *especially* if you are falling behind
  Tutors will not judge you for falling behind
- Always try to *understand*, instead of just memorise
  Understanding something makes it easier to remember
  Exam questions will be different from what you've seen
- Programming is a skill that improves with practice
  The more you practice, the easier labs, assignments and the exam will be

Advice

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Engage, ask questions, go to consults, do practice exercises...

You can improve if you put in the effort!

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COMP2521 material drawn from...

- slides by Jashank Jeremy (COMP2521 19T0)
- slides by Angela Finlayson (COMP2521 18x1)
- slides by John Shepherd (COMP1927 16s2)
- slides by Gabriele Keller (COMP1927 12s2)
- lectures by Richard Buckland (COMP1927 09s2)
- slides by Manuel Chakravarty (COMP1927 08s1)
- notes by Aleks Ignjatovic (COMP2011 '05)
- slides and books by Robert Sedgewick
- Book Cormen, Thomas H.; Lieserson, Charles E.; Rivest, Ronald L.; Stein, Clifford, Introduction to Algorithms (4th ed.). MIT Press and McGraw-Hill, 2022
- slides by Kevin Luxa (COMP2521 25T1)

The Tools of the Trade

Compilation

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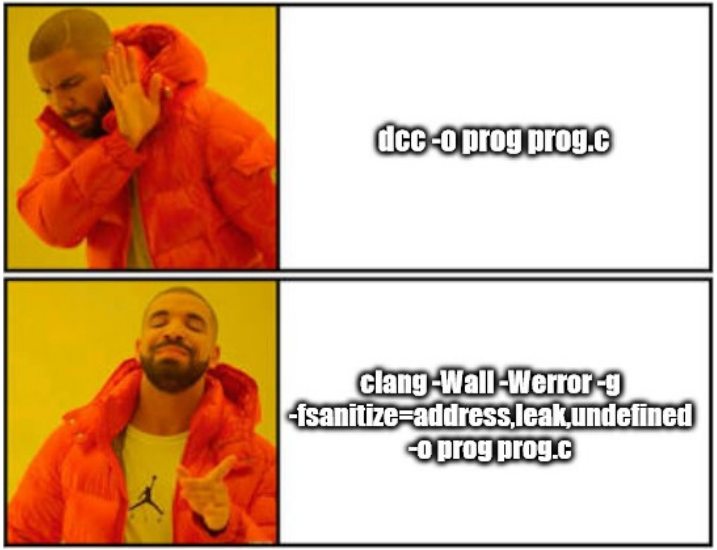

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Compilation

clang

COMP2521 uses the clang compiler. Basic compilation command:

```
clang -Wall -Werror -g -o prog prog.c
```

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Compilation

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- `-Wall` enables (almost) all warnings
  - Catches many possible syntax errors

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Compilation

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  - Catches many possible syntax errors
- `-Werror` turns warnings into errors
  - Prevents compilation if there are warnings

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Compilation

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- `-Wall` enables (almost) all warnings
  - Catches many possible syntax errors
- `-Werror` turns warnings into errors
  - Prevents compilation if there are warnings
- `-g` preserves information useful for debugging
  - Line numbers, function and variable names, etc.

Sanitizers

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{Address, Leak, Memory, Thread, DataFlow, UndefinedBehavior}Sanitizer

a family of compiler plugins, developed by Google
which instrument executing code with sanity checks
use-after-free, array overruns, value overflows, uninitialised values, and more

you've been using ASan+UBSan already: *dcc* uses them!
usable on your own *nix systems (Linuxes, BSDs, 'macOS') too!

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Sanitizers

AddressSanitizer

- Detects invalid memory accesses, such as:
  - Out-of-bounds array accesses
  - Use-after-free errors
  - Double-free errors
  - ...and many others
- To use AddressSanitizer, compile with `-fsanitize=address`
  - Our Makefiles compile with AddressSanitizer by default

Sanitizers

AddressSanitizer - Example

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```c
#include <stdio.h>

#define SIZE 5

int main(void) {
    int arr[SIZE];
    int i = 0;
    while (scanf("%d", &arr[i]) == 1) {
        i++;
    }
    ...
}
```

Sanitizers

AddressSanitizer - Example

```
=================================================================
==2848814==ERROR: AddressSanitizer: stack-buffer-overflow on address 0x7ffc9a6b8b74
at pc 0x00000043ab36 bp 0x7ffc9a6b8a00 sp 0x7ffc9a6b8180
WRITE of size 4 at 0x7ffc9a6b8b74 thread T0
    #0 0x43ab35 in scanf_common(void*, int, bool, char const*, __va_list_tag*) (/imp
ort/glass/2/.../asan+0x43ab35)
    #1 0x43b98b in __isoc99_scanf (/import/glass/2/.../asan+0x43b98b)
    #2 0x4c805f in main /import/glass/2/.../asan.c:9:12
    #3 0x7f0c20c7ed09 in __libc_start_main csu/../csu/libc-start.c:308:16
    #4 0x41e2b9 in _start (/import/glass/2/.../asan+0x41e2b9)

Address 0x7ffc9a6b8b74 is located in stack of thread T0 at offset 52 in frame
    #0 0x4c7f5f in main /import/glass/2/.../asan.c:6

  This frame has 1 object(s):
    [32, 52) 'arr' (line 7) <== Memory access at offset 52 overflows this variable
HINT: this may be a false positive if your program uses some custom stack unwind mec
hanism, swapcontext or vfork
      (longjmp and C++ exceptions *are* supported)
SUMMARY: AddressSanitizer: stack-buffer-overflow (/import/glass/2/.../asan+0x43ab35)
 in scanf_common(void*, int, bool, char const*, __va_list_tag*)
```

Sanitizers

LeakSanitizer

- Detects memory leaks
- To use LeakSanitizer, compile with `-fsanitize=leak`
- Example of error that would be caught by LeakSanitizer:

```c
#include <stdlib.h>

int main(void) {
    int *a = malloc(sizeof(int));
    *a = 42;
    // free(a);
}
```

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MemorySanitizer

- Detects uninitialized memory access
- To use MemorySanitizer, compile with `-fsanitize=memory`
- Example of error that would be caught by MemorySanitizer:

```c
#include <stdio.h>

int main(void) {
    int arr[10];
    arr[0] = 42;
    if (arr[1] == 0) {
        printf("zero\n");
    }
}
```

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Sanitizers

UndefinedBehaviorSanitizer

- Detects wide range of undefined behaviours
- To use UndefinedBehaviorSanitizer, compile with `-fsanitize=undefined`
- Example of error that would be caught by UndefinedBehaviorSanitizer:

```c
#include <limits.h>
#include <stdio.h>

int main(void) {
    int a = INT_MAX;
    printf("%d\n", a + 1);
}
```

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valgrind

- finding memory leaks
  ... not `free`'ing memory that you `malloc`'d
- finding memory errors
  ... illegally trying access memory

```
$ valgrind ./prog
...
==29601== HEAP SUMMARY:
==29601==     in use at exit: 64 bytes in 1 blocks
==29601==   total heap usage: 1 allocs, 0 frees, 64 bytes allocated
==29601==
==29601== LEAK SUMMARY:
==29601==    definitely lost: 64 bytes in 1 blocks
```

Valgrind doesn't play well with ASan. Compile without ASan if you want to use it.

make

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Can't be bothered typing long compilation commands?

make lets you specify
rules, *dependencies*, *variables*
in a Makefile
to define what a program needs to be compiled

With a Makefile, all you need to do to compile is to type
`make`