Week 10: Randomised Algorithms, Algorithm and Data Ethics, Course Review

Randomised Algorithms

Algorithms employ randomness to

- improve worst-case runtime
- compute correct solutions to hard problems more efficiently but with low probability of failure
- compute approximate solutions to hard problems

Randomness

Randomness is also useful

- in computer games:
  - may want aliens to move in a random pattern
  - the layout of a dungeon may be randomly generated
  - may want to introduce unpredictability
- in physics/applied maths:
  - carry out simulations to determine behaviour
    - e.g. models of molecules are often assume to move randomly
- in testing:
  - *stress test* components by bombarding them with random data
  - random data is often seen as *unbiased data*
    - gives average performance (e.g. in sorting algorithms)
- in cryptography

Sidetrack: Random Numbers

How can a computer pick a number at random?

- it cannot

Software can only produce *pseudo random numbers*.

- a pseudo random number is one that is predictable
  - (although it may appear unpredictable)

⇒ Implementation may deviate from expected theoretical behaviour

... Sidetrack: Random Numbers

The most widely-used technique is called the *Linear Congruential Generator (LCG)*

- it uses a recurrence relation:
  - $X_{n+1} = (a \cdot X_n + c) \bmod m$, where:
    - m is the "modulus"
    - a, 0 < a < m is the "multiplier"
    - c, 0 ≤ c ≤ m is the "increment"
    - X_0 is the "*seed*"
  - if c=0 it is called a *multiplicative congruential generator*

LCG is not good for applications that need extremely high-quality random numbers

- the period length is too short
- *period length* ... length of sequence at which point it repeats itself
- a short period means the numbers are correlated

... Sidetrack: Random Numbers

Trivial example:

- for simplicity assume c=0
- so the formula is $X_{n+1} = a \cdot X_n \bmod m$
- try a=11=X_0, m=31, which generates the sequence:

```
11, 28, 29, 9, 6, 4, 13, 19, 23, 5, 24, 16, 21, 14, 30, 20, 3, 2, 22, 25,
27, 18, 12, 8, 26, 7, 15, 10, 17, 1, 11, 28, 29, 9, 6, 4, 13, 19, 23, 5,
24, 16, 21, 14, 30, 20, 3, 2, 22, 25, 27, 18, 12, 8, 26, 7, 15, 10, 17, 1,
11, 28, 29, 9, 6, 4, 13, 19, 23, 5, 24, 16, 21, 14, 30, 20, 3, 2, 22, 25, 27,
18, 12, 8, 26, 7, 15, 10, 17, 1, 11, 28, 29, 9, 6, 4, 13, 19, 23, 5, 24, 16,
21, 14, 30, 20, 3, 2, 22, 25, 27, 18, 12, 8, 26, 7, 15, 10, 17, 1, 11, 28,
29, 9, 6, 4, 13, 19, 23, 5, 24, 16, 21, 14, 30, 20, 3, 2, 22, 25, 27, 18,
12, 8, 26, 7, 15, 10, 17, 1, ...
```

- all the integers from 1 to 30 are here
- period length = 30

... Sidetrack: Random Numbers

Another trivial example:

- again let c=0
- try a=12=X_0 and m=30
  - that is, $X_{n+1} = 12 \cdot X_n \bmod 30$
  - which generates the sequence:

```
12, 24, 18, 6, 12, 24, 18, 6, 12, 24, 18, 6, 12, 24, 18, 6, 12, 24, 18, 6,
12, 24, 18, 6, 12, 24, 18, 6, 12, 24, 18, 6, ...
```

- notice the period length (= 4) ... clearly a terrible sequence

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... Sidetrack: Random Numbers

It is a complex task to pick good numbers. A bit of history:

Lewis, Goodman and Miller (1969) suggested

- $X_{n+1} = 7^5 \cdot X_n \; mod \; (2^{31}-1)$
- note:
  - 7^5 is 16807
  - 2^{31}-1 is 2147483674
  - X_0 = 0 is not a good seed value

Most compilers use LCG-based algorithms that are slightly more involved; see www.mscs.dal.ca/~selinger/random/ for details (including a short C program that produces the exact same pseudo-random numbers as `gcc` for any given seed value)

... Sidetrack: Random Numbers

- Two functions are required:

  ```
  srand(unsigned int seed) // sets its argument as the seed

  rand() // uses a LCG technique to generate random
         // numbers in the range 0 .. RAND_MAX
  ```

  where the constant `RAND_MAX` is defined in `stdlib.h`
  (depends on the computer: on the CSE network, RAND_MAX = 2147483647)

- The period length of this random number generator is very large
  approximately 16 · ((2^{31}) - 1)

... Sidetrack: Random Numbers

To convert the return value of `rand()` to a number between 0 .. RANGE

- compute the remainder after division by RANGE+1

Using the remainder to compute a random number is not the best way:

- can generate a 'better' random number by using a more complex division
- but good enough for most purposes

Some applications require more sophisticated, *cryptographically secure* pseudo random numbers

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Exercise #1: Random Numbers

Write a program to simulate 10,000 rounds of Two-up.

- Assume a $10 bet at each round
- Compute the overall outcome and average per round

```
#include <stdlib.h>
#include <stdio.h>

#define RUNS 10000
```

```
#define BET  10

int main(void) {
   srand(1234567);       // choose arbitrary seed
   int coin1, coin2, n, sum = 0;
   for (n = 0; n < RUNS; n++) {
      do {
         coin1 = rand() % 2;
         coin2 = rand() % 2;
      } while (coin1 != coin2);
      if (coin1==1 && coin2==1)
         sum += BET;
      else
         sum -= BET;
   }
   printf("Final result: %d\n", sum);
   printf("Average outcome: %f\n", (float) sum / RUNS);
   return 0;
}
```

... Sidetrack: Random Numbers

Seeding

There is one significant problem:

- every time you run a program with the same seed, you get exactly the same sequence of 'random' numbers (why?)

To vary the output, can give the random seeder a starting point that varies with time

- an example of such a starting point is the current time, `time(NULL)`
  (NB: this is different from the UNIX command `time`, used to measure program running time)

```
#include <time.h>
time(NULL) // returns the time as the number of seconds
           // since the Epoch, 1970-01-01 00:00:00 +0000

// time(NULL) on July 31st, 2020, 12:59pm was 1596164340
// time(NULL) about a minute later was 1596164401
```

Randomised Algorithms

Analysis of Randomised Algorithms

Math needed for the analysis of randomised algorithms:

Sample space... $\Omega = \{\omega_1,...,\omega_n\}$
Probability... $0 \le P(\omega_i) \le 1$
Event... $E \subseteq \Omega$

- Basic probability theory
  - $P(E) = \Sigma_{\omega \in E} P(\omega)$
  - $P(\Omega) = 1$
  - $P(not\ E) = P(\Omega \backslash E) = 1 - P(E)$
  - $P(E_1\ and\ E_2) = P(E_1 \cap E_2) = P(E_1) \cdot P(E_2)$ if E_1, E_2 *independent*
- Expectation
  - event E has probability $p \Rightarrow$ average number of trials needed to see E is $1/p$

- Combinatorics
  - number of ways to choose k objects from n objects...

$$\binom{n}{k} = \frac{n \cdot (n-1) \cdot \ldots \cdot (n-k+1)}{1 \cdot 2 \cdot \ldots \cdot k}$$

Exercise #2: Basic Probability

Consider Ω = {HH, HT, TH, TT} (each outcome with probability ¼)

1. E_1 = first coin lands on heads. What is $P(E_1)$?
2. E_2 = second coin lands on tails. What is $P(E_2)$?
3. Are E_1,E_2 independent?
4. Probability of not (E_1 and E_2)?
5. On average, how often do you have to toss the pair of coins to obtain HH or TT?

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1. ½
2. ½
3. Yes
4. 1 – ¼·¼ = ¾
5. 2 times

   Note that $2 = \frac{1}{½}$ is the infinite sum

   $$\frac{1}{2} \cdot 1 + \left(1 - \frac{1}{2}\right) \cdot \frac{1}{2} \cdot 2 + \left(1 - \frac{1}{2}\right)^2 \cdot \frac{1}{2} \cdot 3 + \left(1 - \frac{1}{2}\right)^3 \cdot \frac{1}{2} \cdot 4 + \ldots$$

... Analysis of Randomised Algorithms

Randomised algorithm to find *some* element with key k in an unordered array:

```
findKey(L,k):
|  Input  array L, key k
|  Output some element in L with key k
|
|  repeat
|     randomly select e∈L
|  until key(e)=k
|  return e
```

... Analysis of Randomised Algorithms

Analysis:

- *p* ... ratio of elements in *L* with key *k*   (e.g. $p = \frac{1}{3}$)
- *Probability of success*: 1   (if *p* > 0)
- *Expected runtime*: $\frac{1}{p}$
  - Example: a third of the elements have key *k* ⇒ expected number of iterations = 3

... Analysis of Randomised Algorithms

If we cannot guarantee that the array contains any elements with key *k* ...

```
findKey(L,k,d):
|  Input  array L, key k, maximum #attempts d
|  Output some element in L with key k
|
|  repeat
|  |  if d=0 then
|  |     return failure
|  |  end if
|  |  randomly select e∈L
|  |  d=d-1
|  until key(e)=k
|  return e
```

... Analysis of Randomised Algorithms

Analysis:

- *p* ... ratio of elements in *L* with key *k*
- *d* ... maximum number of attempts
- *Probability of success*: 1 - (1-*p*)^{d}
- *Expected runtime*: $\left(\sum_{i=1..d-1} i \cdot (1-p)^{i-1} \cdot p\right) + d \cdot (1-p)^{d-1}$
  - *O(1)* if *d* is a constant

Randomised Quicksort

Quicksort applies divide and conquer to sorting:

- Divide
  - pick a *pivot* element
  - move all elements smaller than the *pivot* to its left
  - move all elements greater than the *pivot* to its right
- Conquer
  - sort the elements on the left
  - sort the elements on the right

Non-randomised Quicksort

Divide ...

```
partition(array,low,high):
|  Input  array, index range low..high
|  Output selects array[low] as pivot element
|         moves all smaller elements between low+1..high to its left
|         moves all larger elements between low+1..high to its right
|         returns new position of pivot element
|
|  pivot_item=array[low], left=low+1, right=high
|  repeat
|  |  right = find index of rightmost element <= pivot_item
|  |  left  = find index of leftmost element > pivot_item    // left=right if none
|  |  if left<right then
|  |     swap array[left] with array[right]
|  |  end if
|  until left≥right
|  if low<right then
|     swap array[low] with array[right]       // right is final position for pivot
|  end if
|  return right
```

... Non-randomised Quicksort

... and Conquer!

```
Quicksort(array,low,high):
|  Input  array, index range low..high
|  Output array[low..high] sorted
|
|  if high > low then     // termination condition low >= high
|  |  pivot = partition(array,low,high)
|  |  Quicksort(array,low,pivot-1)
|  |  Quicksort(array,pivot+1,high)
|  end if
```

... Non-randomised Quicksort


```
3  6  5  2  4  1    // swap a[left=1] and a[right=5]

3  1  5  2  4  6    // swap a[left=2] and a[right=3]

3  1  2  5  4  6    // swap pivot and a[right=2]

2  1   | 3 |   5  4  6

1  2   | 3 |   5  4  6

1  2   | 3 |   4   | 5 |   6
```

Worst-case Running Time

Worst case for Quicksort occurs when the pivot is the unique minimum or maximum element:

- One of the intervals `low..pivot-1` and `pivot+1..high` is of size *n-1* and the other is of size 0
  ⇒ running time is proportional to $n + n\text{-}1 + \ldots + 2 + 1$
- Hence the worst case for non-randomised Quicksort is $O(n^2)$

```
1   2   3   4   5   6

1   |   2   3   4   5   6

1   |   2   |   3   4   5   6

                ...

1   |   2   |   3   |   4   |   5   |   6
```

Randomised Quicksort


```
partition(array,low,high):
|  Input  array, index range low..high
|  Output randomly select a pivot element from array[low..high]
|         moves all smaller elements between low..high to its left
|         moves all larger elements between low..high to its right
|         returns new position of pivot element
|
|  randomly select pivot_index∈[low..high]
|  pivot_item=array[pivot_index], swap array[low] with array[pivot_index]
|  left=low+1, right=high
|  repeat
|  |  right = find index of rightmost element <= pivot_item
|  |  left  = find index of leftmost element > pivot_item    // left=right if none
|  |  if left<right then
|  |     swap array[left] with array[right]
|  |  end if
|  until left≥right
|  if low<right then
|     swap array[low] with array[right]       // right is final position for pivot
|  end if
|  return right
```

... Randomised Quicksort

Analysis:

- Consider a recursive call to `partition()` on an index range of size *s*
  - *Good call*:
    both `low..pivot-1` and `pivot+1..high` shorter than ¾·*s*

    - *Bad call*:
      one of `low..pivot-1` or `pivot+1..high` greater than ¾·*s*
- Probability that a call is good: 0.5
  (because half the possible pivot elements cause a good call)

Example of a bad call:

```
6  3  7  5  8  2  4  1

4  3  6  5  1  2   | 7 |   8
```

Example of a good call:

```
4  3  6  5  1  2   | 7 |   8

1  2   | 3 |   5  6  4   | 7 |   8
```

... Randomised Quicksort

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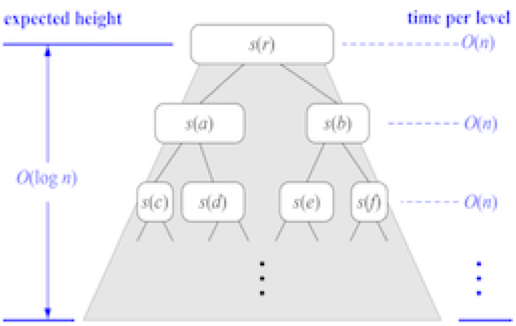
n ... size of array

From probability theory we know that the expected number of coin tosses required in order to get k heads is 2·k

- For a recursive call at depth *d* we expect
    - *d*/2 ancestors are good calls
      ⇒ size of input sequence for current call is $\le (3/4)^{d/2} \cdot n$
- Therefore,
    - the input of a recursive call at depth $2 \cdot \log_{4/3} n$ has expected size 1
      ⇒ the expected recursion depth thus is *O(log n)*
- The total amount of work done at all the nodes of the same depth is *O(n)*

Hence the expected runtime is *O(n·log n)*



Minimum Cut Problem

33/85

Given:

- undirected graph *G=(V,E)*

Cut of a graph ...

- a partition of *V* into $S \cup T$
  - *S,T* disjoint and both non-empty
- its *weight* is the number of edges between *S* and *T*:

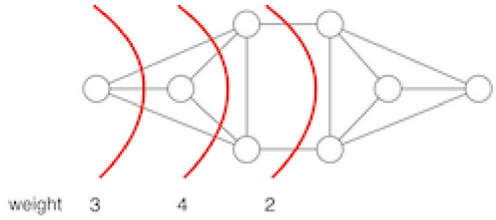
$$\omega(S,T) = |\{ \{s,t\} \in E : s \in S, t \in T \}|$$

Minimum cut problem ... find a cut of *G* with minimal weight

---

... Minimum Cut Problem

Example:

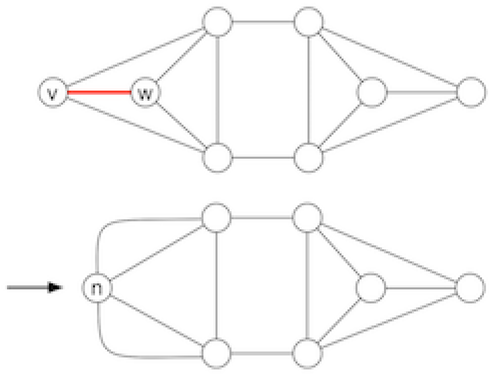


Contraction

Contracting edge *e = {v,w}* ...

- remove edge *e*
- replace vertices *v* and *w* by new node *n*
- replace all edges *{x,v}, {x,w}* by *{x,n}*

... results in a *multigraph* (multiple edges between vertices allowed) Example:



... Contraction

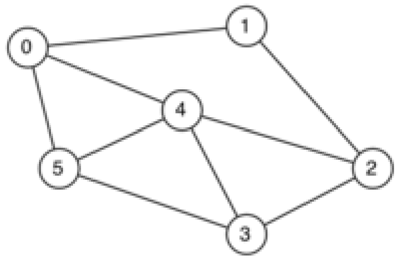
Randomised algorithm for *graph contraction* = repeated edge contraction until 2 vertices remain

```
contract(G):
|  Input  graph G = (V,E) with |V|≥2 vertices
```

```
|   Output cut of G
|
|   while |V|>2 do
|      randomly select e∈E
|      contract edge e in G
|   end while
|   return the only cut in G
```

Exercise #3: Graph Contraction

Apply the contraction algorithm twice to the following graph, with different random choices:



... Contraction

Analysis:

V ... number of vertices

- Probability of `contract` to result in a minimum cut:
$$\geq 1 / \binom{V}{2}$$
- This is much higher than the probability of picking a minimum cut at random, which is
$$\leq \binom{V}{2} / (2^{V-1} - 1)$$
because every graph has 2^{V-1}-1 cuts, of which at most $\binom{V}{2}$ can have minimum weight
- Single edge contraction can be implemented in *O(V)* time on an adjacency-list representation ⇒ total running time: $O(V^2)$

  (Best known implementation uses *O(E)* time)

Karger's Algorithm

Idea: Repeat random graph contraction several times and take the best cut found

```
MinCut(G):
|   Input  graph G with V≥2 vertices
|   Output smallest cut found
|
|   min_weight=∞,  d=0
```

```
|  repeat
|  |  cut=contract(G)
|  |  if weight(cut)<min_weight then
|  |     min_cut=cut, min_weight=weight(cut)
|  |  end if
|  |  d=d+1
|  until d > binomial(V,2) • ln V
|  return min_cut
```

... Karger's Algorithm

Analysis:

V ... number of vertices
E ... number of edges

- *Probability of success*: $\geq 1 - \dfrac{1}{V}$
  - probability of not finding a minimum cut when the contraction algorithm is repeated $d = \binom{V}{2} \cdot \ln V$ times:

$$\leq \left[1 - 1 \middle/ \binom{V}{2}\right]^d \leq \frac{1}{e^{\ln V}} = \frac{1}{V}$$

- Total running time: *O(E·d) = O(E·V²·log V)*
  - assuming edge contraction implemented in *O(E)*

Sidetrack: Maxflow and Mincut

Given: flow network *G=(V,E)* with

- edge weights *w(u,v)*
- source *s∈V*, sink *t∈V*

Cut of flow network *G* ...

- a partition of *V* into *S ∪ T*
  - *s∈ S*, *t∈T*, *S* and *T* disjoint
- its *weight* is the sum of the weights of the edges between *S* and *T*:

$$\omega(S,T) = \sum_{u\in S}\sum_{v\in T} w(u,v)$$

Minimum cut problem ... find cut of a network with minimal weight

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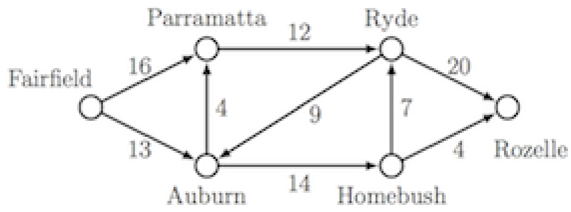
Exercise #4: Cut of Flow Networks

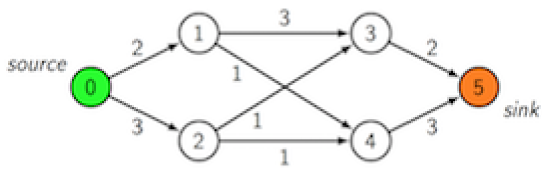


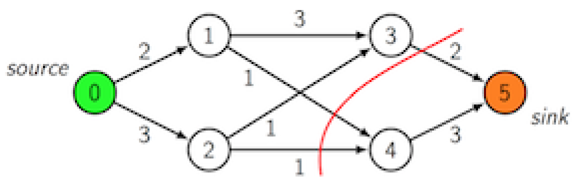
What is the weight of the cut {Fairfield,Parramatta,Auburn}, {Ryde,Homebush,Rozelle}?

12+14 = 26

Exercise #5: Cut of Flow Networks

Find a minimal cut in:





$\omega(S,T)$ = 4

... Sidetrack: Maxflow and Mincut

Max-flow Min-cut Theorem.
In a flow network G the following conditions are equivalent:

1. f is a maximum flow in G
2. the residual network G relative to f contains no augmenting path
3. value of flow f = weight of some minimum cut (S,T) of G

Randomised Algorithms for NP-hard Problems

Many NP-hard problems can be tackled by randomised algorithms that

- compute nearly optimal solutions
  - with high probability

Examples:

- travelling salesman
- constraint satisfaction problems, satisfiability
- ... and many more

Simulation

Simulation

In some problem scenarios

- it is difficult to devise an analytical solution
- so build a software *model* and run *experiments*

Examples: weather forecasting, traffic flow, queueing, games

Such systems typically require random number generation

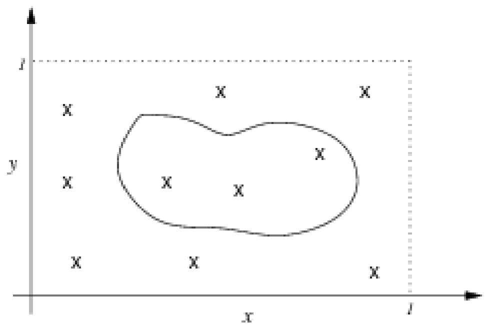
- distributions: uniform, numerical, normal, exponential

Accuracy of results depends on accuracy of model.

Example: Area inside a Curve

Scenario:

- have a closed curve defined by a complex function
- have a function to compute "X is inside/outside curve?"



... Example: Area inside a Curve

Simulation approach to determining the area:

- determine a region completely enclosing curve
- generate very many random points in this region
- for each point *x*, compute *inside(x)*
- count number of insides and outsides
- areaWithinCurve = totalArea * insides/(insides+outsides)

i.e. we approximate the area within the curve by using the ratio of points inside the curve against those outside

This general method of approximating is known as Monte Carlo estimation.

Summary

- Analysis of randomised algorithms
  - *probability of success*
  - *expected runtime*
- Randomised Quicksort
- Karger's algorithm
- Simulation
  - Suggested reading:
    - Moffat, Ch. 9.3, 9.5

Algorithm and Data Ethics

Data Breaches

Major incidents ...

- *TJ Maxx credit and debit card theft* (2005-07)

  Hackers gained access to accounts of over 100 million customers
  ⇒ Customers exposed to credit/debit card fraud

- *Yahoo! data breach* (2013-16)

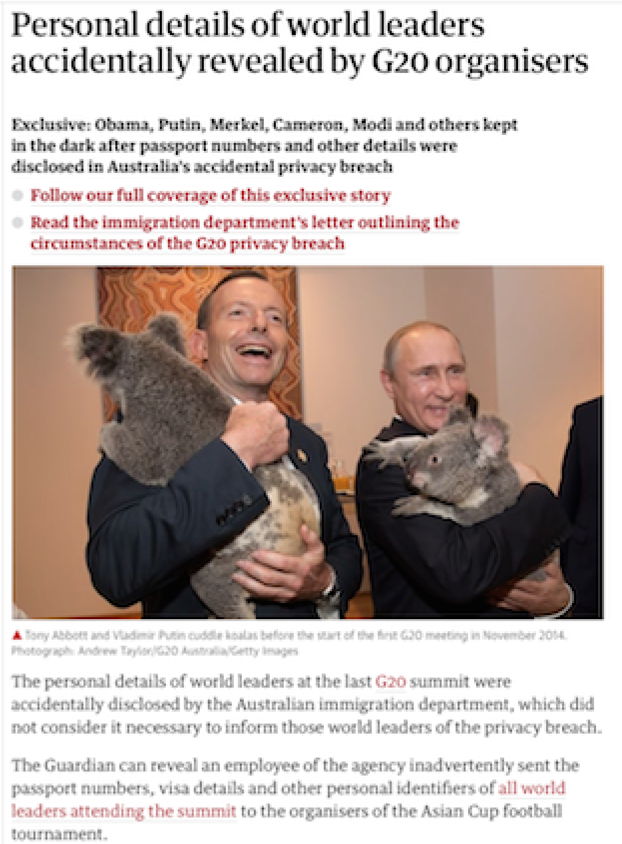
  Hackers gained access to all 3 billion user accounts
  Details taken included names, DOBs, passwords, answers to security questions
  ⇒ Customers exposed to identity theft
  ⇒ Over 20 class-action lawsuits filed against Yahoo!

- *Facebook-Cambridge Analytica data scandal* (2018)

  Millions of people's Facebook profiles used for political purpose without their consent
  ⇒ Cambridge Analytica went bust as a consequence

... Data Breaches

The Guardian, 30/03/15 ...



Personal details of world leaders accidentally revealed by G20 organisers

Exclusive: Obama, Putin, Merkel, Cameron, Modi and others kept in the dark after passport numbers and other details were disclosed in Australia's accidental privacy breach

- **Follow our full coverage of this exclusive story**
- **Read the immigration department's letter outlining the circumstances of the G20 privacy breach**

Tony Abbott and Vladimir Putin cuddle koalas before the start of the first G20 meeting in November 2014. Photograph: Andrew Taylor/G20 Australia/Getty Images

The personal details of world leaders at the last G20 summit were accidentally disclosed by the Australian immigration department, which did not consider it necessary to inform those world leaders of the privacy breach.

The Guardian can reveal an employee of the agency inadvertently sent the passport numbers, visa details and other personal identifiers of all world leaders attending the summit to the organisers of the Asian Cup football tournament.

... Data Breaches

More severe, recent incidents in Australia ...

- *Optus cyberattack* (Sept 2022)

  Hacker gained access to personal information of costumers' personal information

  Details taken included names, DOBs, street addresses, driving licence numbers, passport numbers
  ⇒ Customers vulnerable to financial crimes
  ⇒ Around 100,000 new passports had to be issued
  ⇒ Optus could face $millions in fines

... Data Breaches

- *Medibank cyberattack* (Oct 2022)

  ABC News, 26/10/20 ...

Medibank says all customers' personal data compromised by cyber attack

By business reporters Emilia Terzon and Samuel Yang
Posted Wed 26 Oct 2022 at 10:27am, updated Wed 26 Oct 2022 at 2:47pm

Details of 9 million customers taken, including names, DOBs, street addresses, medical diagnoses and procedures

Also passport numbers and visa details for international students stolen

Ransom demanded but refused
⇒ Medical records posted on darknet, including data on abortions, mental health information

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... Data Breaches

Australia's *Privacy Act 1988* ...

- outlines how personal information must be used and managed
- applies to government agencies, businesses and organisations with annual turnover of >$3 million, private health services, ...

Individuals have the right to:

- have access to their personal information
- know why and how information is collected and who it will be disclosed to
- ask to stop unwanted direct marketing

Businesses and organisations must comply with the *Australian Privacy Principles*:

- how to collect personal information
- how (not) to use personal information
- how to secure personal information

... Data Breaches

Australia's Privacy Act 1988   *Notifiable Data Breaches scheme*

In the event of a suspected or known data breach ...

- contain breach where possible

- assess if personal information is likely to result in serious harm to affected individuals
    - individuals must be notified promptly
    - Australian Information Commissioner must also be notified
- take action to prevent future breaches

Data (Mis-)use

In 2012 several newspapers reported that ...

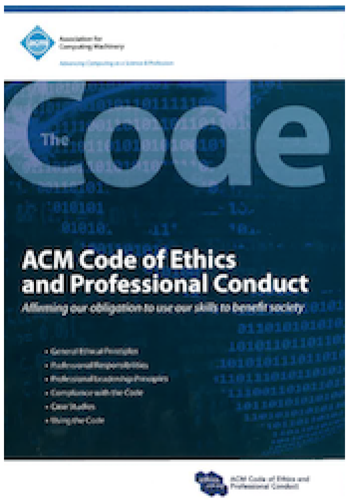
- Target used data analysis to predict whether female customers are likely pregnant
- Target then sent coupons by mail
- A Minneapolis man thus found out about the pregnancy of his teenage daughter

Not based on a factual story, but not implausible either

Who "owns" your data?

- big companies (Google, Facebook, ...)?
- governments?
- you?

... Data (Mis-)use



- Respect privacy
    - Store only the minimum amount of personal information necessary
    - Prevent re-identification of anonymised data
- Carefully analyse the consequences of data aggregation
- Access data only when authorised or compelled by the public good
    - Whistleblower Manning's disclosing of classified military data to Wikileaks (2010-11)
    - Paradise papers that disclosed offshore investments (2017)

Source: *ACM Code of Ethics and Professional Conduct*

Costly Software Errors

NASA's Mars Climate Orbiter ...

- launched 11/12/1998
- reached Mars on 23/9/1999
- came too close to surface and disintegrated

Cause of failure:

- spec said impulse must be calculated in *newton seconds*
- one module calculated impulse in *pound-force seconds*
- 1 newton ≅ 0.2248 pound-force

... Costly Software Errors

Toyota vehicle recall (2009-11)

- Vehicles experienced sudden unintended acceleration
- 89 deaths have been linked to the failure
- 9 million cars recalled worldwide

Causes of failure included ...

- a deficiency in the electronic throttle control system:
  stack overflow
  ⇒ stack grew out of boundary, overwrote other data

... Costly Software Errors

Sydney Morning Herald, 05/01/10:

BUSINESS

Welcome to 2016: Eftpos glitch spreads

By Chris Zappone
5 January 2010 — 10:32am

A A A

The computer bug that brought Bank of Queensland's Eftpos transactions to a grinding halt in the first days of the New Year has hit other banks - including the Commonwealth Bank-owned BankWest.

The glitch, which started on January 1, left Australian retailers struggling to perform routine electronic point-of-sale transactions.

Merchants instead had to rely on carbon vouchers provided by banks or temporary measures that overrode the machines' internal time stamp.

Because of the error, Eftpos terminals recognise the year as 2016.

EFTPOS terminals inoperable for several days in early 2010

- customers' cards rejected as expired

Cause of failure:

- one module interpreted the current year as hexadecimal
  - `0x09 = 09`
  - `0x10 = 16` ($\neq$ 10)

Sidetrack: Year 2038 Problem

Recall:

```
#include <time.h>
time(NULL) // returns the time as the number of seconds
           // since the Epoch, 1970-01-01 00:00:00 +0000
```

Year 2038 problem ...

- `time(NULL)` on 19 January 2038 at 03:14:07 (UTC) will be `2147483647 = 0x7FFFFFFF`
- a second later it will be `0x80000000` = -2,147,483,648
- ⇒ -2^{31} seconds since 01/01/1970 ("Epoch") is 13 December 1901 ...

Programming Ethics

From the *ACM/IEEE Software Engineering Code* ...

- Software engineers shall ensure that their products meet the highest professional standards possible
  - Strive to fully understand the specifications for software
  - Ensure that specifications have been well documented and satisfy the users' requirements
  - Ensure adequate testing, debugging, and review of software and related documents
- Approve software only if it
  - is safe
  - meets specifications
  - passes appropriate tests
  - does not diminish quality of life, diminish privacy or harm the environment

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... Programming Ethics

Algorithms can save lives.

Uberlingen airplane collision 1/7/02 at 11:35pm ...

- passenger jet V9 2937 and cargo jet QY 611 on collision course at 36,000 feet
- ground air traffic controller instructed V9 pilot to descend
- seconds later, the automatic Traffic Collision Avoidance System (TCAS)
  - instructed V9 2937 to climb
  - instructed QY 611 to descend
- flight 611's pilot followed TCAS, flight 2937's pilot ignored TCAS
- all 71 people on board the two planes killed

⇒ Collision would not have occurred had both pilots followed TCAS

Exercise #6: Collision Avoidance Algorithm

The TCAS ...

- builds 3D map of aircraft in the airspace
- determines if collision threat occurs
- automatically negotiates mutual avoidance manoeuvre
- gives synthesised voice instructions to pilots ("climb, climb")

What algorithm would you use for reaching an agreement (climb vs. descent)?

Moral Dilemmas

How to program an autonomous car ...

- for a potential crash scenario
- when you have to choose between two actions that are both harmful

This is a modern version of the *Trolley Problem* ...

- A runaway trolley is on course to kill five people
- You stand next to a lever that controls a switch
- If the trolley is diverted, it will kill one person on the side track

Is it ethical to pull the lever and kill the one in order to save the five?

Exercise #7: Moral Dilemmas

What would you do?

Variations:

- Fat man on bridge
- Transplant

⇒ try it yourself on the Moral Machine

Course Review

Course Review

Goal:

For you to become competent Computer Scientists able to:

- choose/develop effective data structures
- choose/develop algorithms on these data structures
- analyse performance characteristics of algorithms (time/space complexity)
- package a set of data structures+algorithms as an abstract data type
- represent data structures and implement algorithms in C

Assessment Summary

```
lab     = mark for programs/quizzes (out of 8+8)
midterm = mark for mid-term test     (out of 12)
assn    = mark for large assignment (out of 12)
exam    = mark for final exam        (out of 60)

if (exam >= 25)
   total = lab + midterm + assn + exam
else
   total = exam * (100/60)
```

To pass the course, you must achieve:

- at least 50/100 for `total`

which implies that you must achieve at least 25/60 for `exam`

... Assessment Summary

Check your results on WebCMS or using

```
prompt$  9024 classrun -sturec
```

```
ClassKey: 22T3COMP9024
...
Exam: 43/60
assn: 8/12
lab: 11.5/16
midterm: 9/12
total: 72/100
```

```
ClassKey: 22T3COMP9024
...
Exam: 23/60
assn: 8/12
lab: 11.5/16
midterm: 9/12
total: 38/100
```

Final Exam

Goal: to check whether you have become a competent Computer Scientist

Requires you to demonstrate:

- understanding of fundamental data structures and algorithms
- ability to analyse time complexity of algorithms
- ability to develop algorithms from specifications

Lectures, problem sets and assignments have built you up to this point.

... Final Exam

2-hour (+10mins reading time) online exam on **Monday 5th December 1:45pm – 4:00pm**

Must start exam between 1:45pm and 1:50pm to get the full 130 minutes (= 2hrs+10mins)

- 8 multiple-choice/short answer questions, 4 open questions
- Covers *all* of the contents of this course
- Each multiple choice/short answer question is worth 4 marks (8 × 4 = 32)
  Each open question is worth 7 marks (4 × 7 = 28)
- Multiple-choice questions can have *one or more* correct options
  - You will get partial marks for partially correct answers

... Final Exam

Sample prac exam available on Moodle

- 2 multiple-choice questions, 2 open questions
- maximum time: 45 minutes
- feedback given immediately
  - marks for multiple-choice questions
  - *sample* solution for open questions

... Final Exam

Of course, assessment isn't a "one-way street" ...

- I get to assess you in the final exam
- you get to assess me in UNSW's MyExperience Evaluation
  - go to https://myexperience.unsw.edu.au/
  - login using *zID@ad.unsw.edu.au* and your zPass

  Response rate (as at Monday week 10): 29% 😰

  Please fill it out ...

  - give me some feedback on how you might like the course to run in the future
  - even if that is "Exactly the same. I liked how it was run."

Revision Strategy

- Re-read lecture slides and example programs
- Read the corresponding chapters in the recommended textbooks
- *Review/solve problem sets*
- Attempt prac exam questions on Moodle
- Invent your own variations of the weekly exercises (problem solving is a *skill* that improves with practice)

Supplementary Exam

If you attend an exam

- you are making a statement that you are "fit and healthy enough"
- it is your only chance to pass (i.e. no second chances)

Supplementary exam *only* available to students who

- do *not* attend the final exam *and*
- apply formally for special consideration
  - with a documented and accepted reason for not attending

If you experience a technical issue:

- Take screenshots of as many of the following as possible:
  error messages, screen not loading, timestamped speed tests, power outage maps
- If issue was severe, apply for Special Consideration after conclusion of exam. Attach screenshots.

Note: Exam has been designed to account for up to 10mins of non-severe technical issues

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Assessment

Assessment is about determining how well *you* understand the syllabus of this course.

If you can't *demonstrate your understanding*, you don't pass.

In particular, we don't pass people just because ...

- please, please, ... my parents will be ashamed of me
- please, please, ... I tried *really hard* in this course
- please, please, ... I'll be excluded if I fail COMP9024
- please, please, ... this is my final course to graduate
- etc. etc. etc.

Failure is a fact of life. For example, my scientific papers or project proposals get rejected sometimes too.

Summing Up ...

So What Was the Real Point?

The aim was for you to become a better computer scientist

- more confident in your own ability to design data structures and algorithms
- with an expanded set of fundamental structures and algorithms to draw on
- able to analyse and justify your choices
- ultimately, enjoying the software design and development process

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Finally ...

Book 9
Epilogue

Thus spake the Master Programmer:

"Time for you to leave."

... Finally ...

T h a t ' s   A l l   F o l k s

&&

Good Luck with the Exams

and with your future studies

😃 👍 🎓

Produced: 14 Nov 2022