

Programming Concepts

Part 2: A language for algorithms

Reading Suggestions

- Dowek. Chapter 1
- Harel. Chapters 1–3

Purpose of algorithms

- Algorithms are designed for person-to-person communication
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 - informal English used for person-to-person communication

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We need to eliminate vagueness:

- make a note of ...
- proceed through the list of records ...
- find record of boss in list ...

Essential features of algorithms

Data storage and manipulation

- make a note of number 0
- make note of name of boss
- add salary to noted number
- add up resulting numbers
- increase the counter

Control structures

- proceed through the employee list
- if salary of boss is less than ... then ...
- when the end of the list is finished

Pseudocode = a human-readable way to write algorithms
using exactly these features

Data storage: VARIABLES or little boxes

Examples:

- “noted number” is a variable
- “increase counter” – “counter” is a variable

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In pseudo code

- VARIABLES are used to store data
- VARIABLES can be updated:
 - $COUNTER \leftarrow 0$
- VARIABLES can be interrogated:
 - $TOTAL \leftarrow SALARY + INCREMENT$
 - $COUNTER \leftarrow COUNTER + 1$
 - $SALARY \leftarrow SALARY * 5$

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What operations can be performed with contents of variables?

Are variables really little boxes?

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These are **choices** : a semantic description is needed

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- “proceed through the list of records”
- “search records for boss of current employee”

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- VARIABLE X:

item

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- VARIABLE X:

item

X

- ARRAY A[1...n]:

item	item	...	item
------	------	-----	------

A[1] A[2] ... A[n]

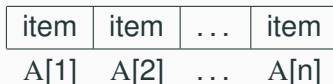
Data storage: arrays

- “proceed through the list of records”
- “search records for boss of current employee”

- VARIABLE X:



- ARRAY A[1...n]:



characteristics of arrays:

- Length of an array is always known:
 - A[1 ... n] has n boxes
- Each box in an array is directly accessible, via index:
 - $A[3] \leftarrow 27$
 - $A[7] \leftarrow B[2] + A[1]$

Control structures

- Direct sequencing:
“do A then do B then do C then do . . .”

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- Conditional iteration:
“do something so long as some condition is true”
number of repetitions depends on evaluation of “condition”

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All available in all programming languages

Direct sequencing

General format:

do A

do B

do C

Direct sequencing

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```
do A
do B
do C
```

Examples

$\text{CURR} \leftarrow 1$

$\text{LAST} \leftarrow 10$

$\text{MIDDLE} \leftarrow$

$(\text{CURR} + \text{LAST}) \text{ div } 2$

Direct sequencing

General format:

```
do A  
do B  
do C
```

Examples

```
TEMP  $\leftarrow$  A[i]  
A[i]  $\leftarrow$  A[j]  
A[j]  $\leftarrow$  TEMP
```

Direct sequencing

General format:

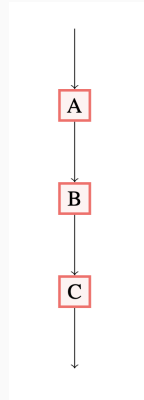
```
do A  
do B  
do C
```

Examples

```
// interchange A[i] with A[j]  
TEMP  $\leftarrow$  A[i]  
A[i]  $\leftarrow$  A[j]  
A[j]  $\leftarrow$  TEMP
```

Picturing direct sequencing

do A
do B
do C



Conditional sequencing

General formats

1.

```
if some condition is true then  
  | do something
```

2.

```
if some condition is true then  
  | do something  
else  
  | do some other thing
```

Conditional sequencing

General formats

1. **if** *some condition is true* **then**
| do something

2. **if** *some condition is true* **then**
| do something
else
| do some other thing

e.g.

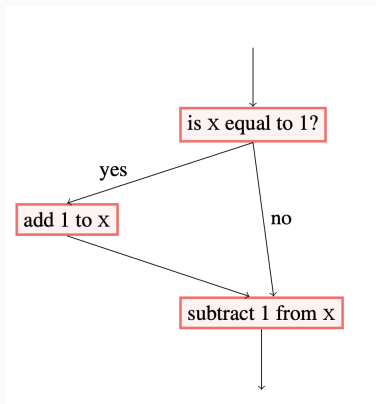
if *sales have decreased* **then**
| lower price by 10%

e.g.

if *price > limit* **then**
| pay x
else
| pay y

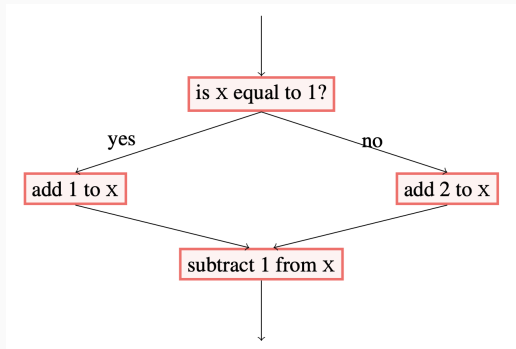
Picturing conditional sequencing

```
if  $X = 1$  then  
|  $X \leftarrow X + 1$   
 $X \leftarrow X - 1$ 
```



Picturing conditional sequencing

```
if  $X = 1$  then  
|  $X \leftarrow X + 1$   
else  
|  $X \leftarrow X + 2$   
 $X \leftarrow X - 1$ 
```



Layout is important

```
if item is taxable then
|   if price > limit then
|   |   pay x
|   else
|   |   pay y
else
|   pay z
```


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Layout is important

if *condition* **then**

| do A

| do B

else

| do C

do D

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| do A
| do B

else

| do C
do D

if *condition* **then**

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| do B

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| do D

Bounded iteration

Do something an exact number of times

General format:

```
for  $i \leftarrow start$  to  $finish$  do  
  |  $something$ 
```

Bounded iteration

Do something an exact number of times

General format:

```
for  $i \leftarrow start$  to  $finish$  do  
  |  $something$ 
```

i : the *iterator*.

Available to use
within the
something

start: value at which the
iterator starts

finish: value at which the
iterator ends

Bounded iteration: Example

Summing the first n positive numbers:

Input: positive number n

Output: sum of first n positive numbers

SUM \leftarrow 0

for $i \leftarrow 1$ **to** n **do**

 | SUM \leftarrow SUM + i

return SUM

Bounded iteration: Example

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Explanation:

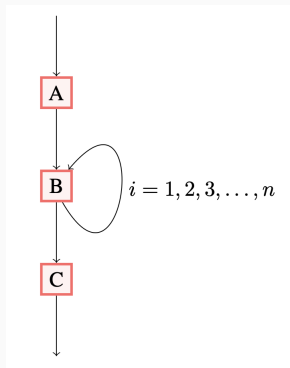
Input: description of expected input

Output: description of desired output

return *value*: an operation in pseudo-code

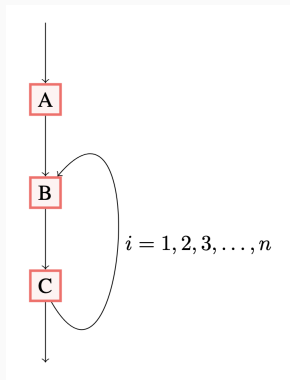
Picturing bounded iteration

```
A
for  $i \leftarrow 1$  to  $n$  do
  | B
C
```



Picturing bounded iteration

```
A
for  $i \leftarrow 1$  to  $n$  do
  | B
  | C
```



Conditional iteration

Perform *something* repeatedly so long as some *condition* remains true

General format:

```
while condition do  
  | something
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Explanation:

- Executing *something* can affect the value of *condition*
- If *condition* is false *something* is not executed
- If *condition* is true *something* is executed and . . . evaluation repeats itself
- The value of *condition* may remain true forever

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Not guaranteed to terminate

Conditional iteration: Example

- Summing numbers:

Input: positive number n

Output: sum of first n positive numbers

SUM \leftarrow 0

ITER \leftarrow 1

while ITER $\leq n$ **do**

 SUM \leftarrow SUM + ITER

 ITER \leftarrow ITER + 1

return SUM

Conditional iteration: Example

- Summing numbers:

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while ITER $\leq n$ **do**

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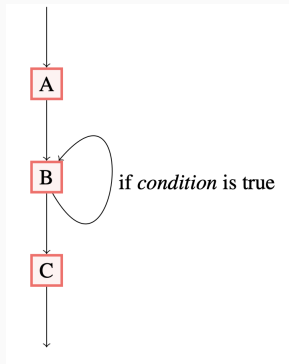
 ITER \leftarrow ITER + 1

return SUM

- Note:
 - ITER needs to be explicitly managed
 - ITER is automatically furnished by for-loop construct

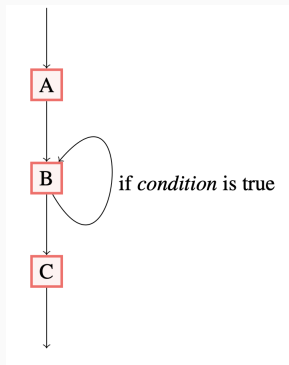
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For more of these pictures, and some a recap of pseudocode, see the [extra notes on pseudocode](#) on Canvas

Layout is important

for $i \leftarrow 2$ to k do

A

B

C

D

Layout is important

for $i \leftarrow 2$ to k do

| A
| B
C
D

for $i \leftarrow 2$ to k do

| A
| B
| C
D

Layout is important

```
if cond1 then
|   while cond2 do
|       |   A
|       |   B
else
|   C
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|       B
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```

- Data storage: variables, arrays
- Control structures: direct sequencing, bounded iteration, conditional sequencing.
- **return** to give back a value at the end

Don't forget: any algorithm must come with a valid specification!

How do you implement these in Python / Java?

Calculating salary bill

Legal inputs: any list of employee records; each record contains their salary

Required output: the total salary bill

Algorithm

- (1) Make a note of number 0
- (2) Proceed through the employee list, each time
 - adding salary to noted number
- (3) When end of list is reached
 - output noted number

Name	Salary
Tom Jones	12000
Mary Clark	17000
Shaun Collins	16000
...	...
Lisa	23000

Pseudo-code for calculating salary bill

Input: an array $E[1 \dots n]$ of employee details

Output: total salary of all employees

Assumptions: array elements contain *salary* field

TOTAL \leftarrow 0

PTR \leftarrow 1

while PTR $\leq n$ **do**

 TOTAL \leftarrow TOTAL + *salary*(E[PTR])

 PTR \leftarrow PTR + 1

return TOTAL

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Somewhat easier with for-loop construct

Details of *salary* extraction ignored

Happy employees

Counting happy employees

Legal inputs: any list of employee records; each record contains their salary and name of boss

Required output: number of employees earning more than their boss

Algorithm ?

- (1) Make a note of counter 0
- (2) Proceed through the employee list, each time
 - (a) Note name of boss, and salary of current employee
 - (b) Find record of boss in list
 - (c) If salary of boss is less than that of current employee, increase the counter
- (3) When end of list is reached, output value of counter

Name	Salary	Boss
Tom	12000	James
Mary	17000	Cindy
Shaun	16000	Tom
...
Lisa	23000	Mary

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...
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Towards pseudo-code

Input: an array $E[1 \dots n]$ of employee details

Output: number of employees earning more than their boss

Assumptions: array elements contain *name*, *salary*, *boss* fields. Every employee has a *boss*

HAPPY \leftarrow 0

for $i \leftarrow 1$ **to** n **do**

 BOSS \leftarrow *boss*($E[i]$)

 SALARY \leftarrow *salary*($E[i]$)

 find PTR satisfying BOSS = *name*($E[\text{PTR}]$)

if *salary*($E[\text{PTR}]$) < SALARY **then**

 HAPPY \leftarrow HAPPY + 1

return HAPPY

Pseudo-code for counting happy employees

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HAPPY $\leftarrow 0$

for $i \leftarrow 1$ **to** n **do**

 BOSS $\leftarrow \text{boss}(E[i])$

 SALARY $\leftarrow \text{salary}(E[i])$

 PTR $\leftarrow 1$

while BOSS $\neq \text{name}(E[\text{PTR}])$ **do**

 | PTR $\leftarrow \text{PTR} + 1$

if $\text{salary}(E[\text{PTR}]) < \text{SALARY}$ **then**

 | HAPPY $\leftarrow \text{HAPPY} + 1$

return HAPPY

What about when an employee might not have a boss?

Summary

- A fixed language. Powerful enough to write **all** algorithms.
- Data storage: Variables and Arrays. Care with indexing.
- Difference between bounded and conditional iteration.
- Layout is **very** important!

To Do:

- Exercise sheet 1: check the solutions.
- Homework 1.
- Exercise sheet 2.

Ask any questions at the Helpdesk/Exercise sessions.