Arrays

- ... when we need to store many elements of the same type (e.g., 1 000 of integer numbers),
- they get defined in the section of variables (i.e., var),
- they get defined using the keyword array, followed by an interval that defines its bounds, and the underlying data-type.
- Example:
```
var a:  array [1..100] of integer;
        file_example:array[5..50] of string;
```
- Individual members are accessed using square brackets:
  Example:
```
a[1]:=10;
file_example[6]:='xxx';
{Beware:} file_example[1]:='out of bounds!';
```

Sieve of Eratosthenes

```
var primes: array[2..1000] of boolean;        i,j:integer;
begin
for i:=2 to 1000 do primes[i]:=true;
for i:=2 to 1000 do
begin
    if primes[i] then
    begin writeln(i,' is a prime');
        j:=2;
        while(i*j<=1000) do
        begin
            primes[i*j]:=false;
            j:=j+1;
        end;
    end;
end
```

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  - binary search (start in the middle, in each step halve the input),
  - quadratic search, generalized quadratic search...

Unary search

- Simple algorithm, simple analysis, its complexity:

Unary search

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- $\Theta(n)$.

Binary search

- What's the complexity of the algorithm? When do we have to add an extra step?

Binary search

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- $\Theta(\log n)$.

Further examples

of array manipulation algorithms and complexity analysis:

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- Any ideas how to beat this complexity?
- Exercise (think about it at home, a solution will be shown later).

Horner's Method

- We want to convert a number stored as a string into an integer.

Number $a_n a_{n-1} a_{n-2} ... a_0$ in decimal (position) system means: $a_n 10^n + a_{n-1} 10^{n-1} + ... + a_0$. It holds:

$$a_n 10^n + a_{n-1} 10^{n-1} + ... + a_0 = (...((a_n * 10) + a_{n-1} * 10) + ... + a_1) * 10 + a_0$$

In the same way we may evaluate numbers in other position systems (binary, ternary, quaternary, decimal, hexadecimal...)

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- ... or we use Horner's method and start with the most important digit.
- We find its value and proceed (inductively):
  Multiply so far obtained result by 10 and add (sum up with) the newly loaded digit.

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In the same way we may evaluate numbers in other position systems (binary, ternary, quaternary, decimal, hexadecimal, ...)

Example

```
program x;
var a:string;
    i,value:longint;
begin
     readln(a); i:=1; value:=0;
     while i<=length(a) do
     begin
          value:=10*value+ord(a[i])-ord('0');
          i:=i+1;
     end;
     writeln(value);
end.
```

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- Brute force (estimate $a_n x^n$, $a_{n-1} x^{n-1}$,... and sum it up)
- or Horner's method:

$$\sum_{i=0}^{n} a_i x^i = ((\ldots(a_n x + a_{n-1})x + \ldots + a_1)x + a_0).$$

Evaluating a polynomial by Horner's method

- 1: Read the coefficient of highest (so far not processed) monomial
- multiply the value obtained so far with x,
- add the value of the newly read coefficient,
- GOTO 1;

Example

```
program nothing;
var i,a,sum,degree,x:integer;
{Evaluate a polynomial for a value x, use variable a
to read the coefficients}
begin
      readln(degree); readln(x);
      sum:=0;
      for i:=0 to degree do
      begin sum:=sum*x;
            readln(a);
            sum:=sum+a;
      end;
      writeln('The value is:  ',sum);
end.
```

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- Then we may use these labels in the program
- and by `goto label;` we perform a jump to the location of the label.
- Never use GOTO (in structured programming). I am using it in pseudocode in order to postpone the introductin of loop constructs after the kernel of the algorithm.

Defining functions and procedures

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- Functions are a part of a program. They are able to process given parameters and to return a result.
- Examples: Cross the street; write out a message; arrive somewhere (by a train); calculate a factorial...

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<u>`function`</u> name(argument :<u>`type`</u>;...):<u>`type_of_result`</u>

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- arguments are listed in parentheses (as if we defined variables).
- Inidividual arguments get separated by a semicolon (while defining).
- After a colon we put the type of the result.
- Value of the result gets assigned into a special variable with the same name as the function has.

Example

```
function sum_up(a:integer; b:integer):integer;
begin
        sum_up:=a+b;
end;
```

Example

```
program x;
var a:integer;


function sum_up(a:integer; b:integer):integer;
begin
        sum_up:=a+b;
end;

begin
        a:=sum_up(5,10);
        writeln(a);
end.
```

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- ```
  function f(a:integer):boolean;
  var b,c:integer;...
  begin...end;
  ```
  ```

Example

```
function sum_up(a:integer; b:integer):integer;
var c:integer;
begin
        c:=a+b;
        sum_up:=c;
end;
```

Note that the variable used to define the result is *write-only*. It must **never** be read! (It could not be distinguished from calling a parameter-less function.)

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Scope resolution

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- Local variables are visible only within the appropriate functions.
- A local variable may have the same name as a global one.
- In case of such a conflict, inside the function only the local variable is visible.
- Values of the parameters are (by default) a value-parameters, i.e., the value of an expression is copied. If the function changes this value, this change is not propagated to the caller.

Example

```
function sum_up(a:integer; b:integer):integer;
begin
        sum_up:=a+b;
        a:=0;
end;
begin
        x:=5; y:=10; c:=sum_up(x,y);
        writeln(x);
end.
```

Reference-parameters

Sometimes we want to propagate the argument-change to the caller. How can we do that?

We use the keyword var in the appropriate place:

```
function f(var a:integer; b:integer):integer;
begin
        a:=5;
        b:=5;
end;
...
x:=0; y:=0; a:=f(x,y);
writeln(x); writeln(y);
...
```

Result: 5 and 0; only genuine variables can be passed as such parameter!

Parameter-free functions

It can make sense to define functions without parameters (e.g., a function reading the data).
Then we omit parentheses behind the function-name (when, both, defining and calling it):

```
function x:integer;
begin
        x:=10;
end;

...
a:=x;
...
```

Procedures

'Procedures are functions that return no value.'

```
procedure name(arguments);

...  name(arguments);...
```

example:

procedure writeit(a:integer;b:integer);
begin
    writeln(a); writeln(b);
    {We output the parameters}
end;

... writeit(5,10);...

Nested Functions and Procedures

It is possible to define a function inside another one:

```
procedure f(a:integer);
    procedure g(b:integer);
    begin
        writeln('Proc.  g in proc.  f w/arg.  ',b);
    end;
begin
    writeln('Procedure f with argument ',a);
    g(2);{Calling nested proc.  g}
end;
```

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- Conflicting names resolve to the most 'local' one.
- In this way we can define 'local' procedures and functions. I.e., nested functions that are visible only inside their direct parents (not from grand-parents and further).

Example

```
procedure f(h:integer);
    procedure g(b:integer);
        procedure h(c:integer);
        begin
            writeln('Procedure h with arg.  ',c);
        end;
    begin
        writeln('Procedure g with arg.  ',b);
        h(5);
    end;
begin
    writeln('Procedure f with arg.  ',h);
    g(3); f(5); {so far so good, but calling
         h(4) here causes an error!}
end;
```