# Applied Programming and Computer Science, DD2325/appcs15

# PODF, Programmering och datalogi för fysiker, DA7011

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Lecture 6, Huffman coding and hashing

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## Tree

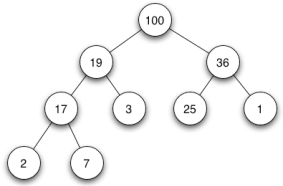
When are trees used?

- Binary heap / Heap sort
- Data compression
- Databases
- File system
- Compiler uses syntax trees
- Chess program
- Decision trees
- ...

## Binary heap

A binary heap is a binary tree with two additional constraints

- Heap property: All nodes are greater(less) than or equal to each of its children
- Shape property: All levels of the tree except the deepest are filly filled (complete binary tree)




Siblings in a heap can be interchanged unless doing so violates the constraints.

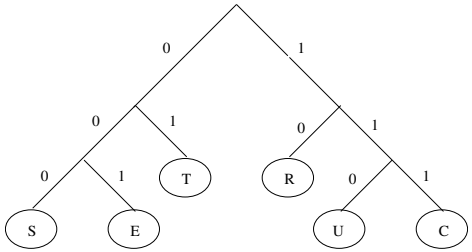
How can we build a heap from a set of data?
Given a binary heap, Heap sort algorithm is straightforward.

## Compression, Huffman code

Every character is coded binary.
The common characters have short code. Less common, longer code. Statistically decided.

Example `TREESTRUCTURE`

The characters $T$, $R$ and $E$ are most common and therefore have short code. The tree structure for the example:



## Compression, Huffman code (cont.)

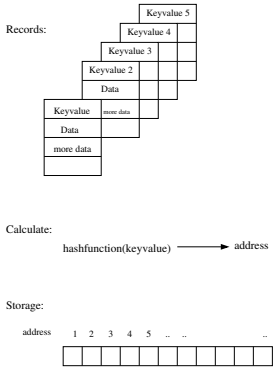
How can `TREESTRUCTURE` be represented in binary code?
How many bits are required in total?

Compare the length with ASCII (using a byte) which ends up with:
13*8 = 104 bits

Compression is used when zipping files, to compress pictures/movies (files) ...

## Hashing

Hashing is a way to obtain both efficient memory use and effective retrieval.
The keyvalue of a record is used to calculate the address where the record is to be stored.




## Hash function

The requirements one can have on the hash function:

- must calculate an address within the legal address space.
- addresses should be evenly distributed in the legal address space.
- easy to calculate an address.

The hash function can result in the same address for different keys.
The collisions can be dealt with `open` or `closed` address hashing.

## Open and closed address hashing

Open address hashing:

Linear probing.
If the keyvalue has given the address to an already occupied space the next adress space is considered.

Closed address hashing:

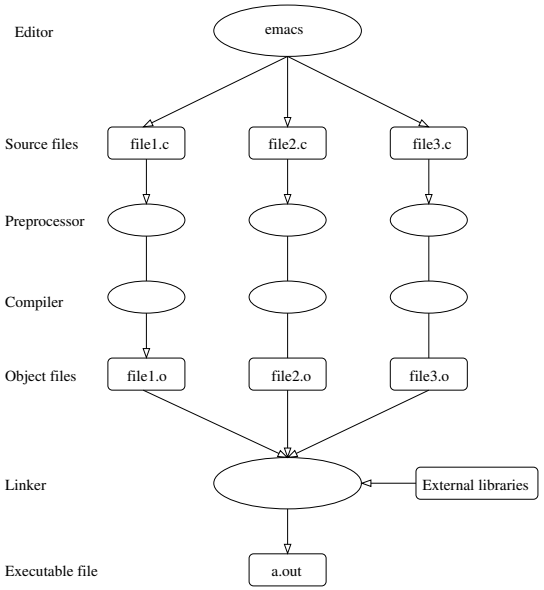
Chained hashing.
Every entry in the storage is a list.
All records with the same address ends up in the same list.

## From problem to executable file

- **Thinking** A problem is formulated, algorithms devised and data structures chosen.
- **Programming** The C program is written using an editor (emacs, xemacs).
- **Preprocessing** Preprocessor directives are interpreted and a preprocessed C file generated (gcc -E, cc -E, cpp).
- **Compiling** The preprocessed source code is translated to object code (machine instructions) (gcc -c, cc -c).
- **Linking** The object code is linked with external libraries to produce an executable (gcc, cc, ld).
- **Debugging** Make sure the program works as expected. Correct possible mistakes (gdb).

The first step is the most important! By considering the problem carefully the debugging time can be significantly reduced.

## Compiling & linking




## Compiling & linking (cont.)

At CSC there are two different C compilers, `cc` (Sun) and `gcc` (GNU). Both can be used for preprocessing, compiling and linking small programs in a single command.

`gcc file.c -o runme`
generates an executable `runme` from the source code in `file.c`.

The object files are linked with the most common libraries (`stdio`, `stdlib` and possibly a few more).

If compiling a program is complicated (several different files, many options, different programming languages, ...) it is convenient to use *Makefiles*.

## Compiler & linker options

In some cases additional information must be supplied for the compiler to generate an executable. These are given as *command line options*. There are also some options useful for debugging and optimizing.

| **Option** | | |
|---|---|---|
| `gcc` | `cc` | **Effect** |
| `-c` | `-c` | Compile source files but do not link |
| `-l`*lib* | `-l`*lib* | Link with library *lib* |
| `-L`*dir* | `-L`*dir* | Add *dir* to library search path |
| `-I`*dir* | `-I`*dir* | Add *dir* to include file search path |
| `-o`*tgt* | `-o`*tgt* | Name executable *tgt* (default:`a.out`) |
| `-O2` | `-fast` | Compile with optimization |
| `-Wall` | `-v` | Print "extra" warning messages |

For a more complete list of options, give the command:
`man gcc` (or `man cc`) at the prompt.

## Compiling – examples

Compile `program.c` and generate executable `target` with optimization,

```
> gcc program.c -O2 -o target
```

Same example, but linked with math library

```
> gcc program.c -O2 -o target -lm
```

Compile files `main.c` and `function.c` and link to obtain executable `runme`

```
> cc -c main.c
> cc -c function.c
> cc function.o main.o -o runme -lm
```

User-defined include files and libraries,

```
> cc program.c -L~/mylibraries -I~/myincludefiles -lmylib
```

(">" is used to indicate that the command is given at the prompt.)

## stack.c

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

int isEmpty(ListNodePtr sPtr){return sPtr == NULL;}

int isFull(ListNodePtr sPtr){return 0;}

void push(ListNodePtr *sPtr, char value){
  ListNodePtr newPtr;
... See lecture notes 5}

char pop(ListNodePtr *sPtr){
  ListNodePtr currPtr;
  char value;
... See lecture notes 5}

void printList (ListNodePtr currPtr){
... See lecture notes 4}
```

## stack.h

```
struct listNode
{
  char data;
  struct listNode *nextPtr;
};

typedef struct listNode ListNode;
typedef ListNode *ListNodePtr;

int isEmpty(ListNodePtr sPtr);

int isFull(ListNodePtr sPtr);

void push(ListNodePtr *sPtr, char value);

char pop(ListNodePtr *sPtr);

void printList (ListNodePtr currPtr);
```

## main.c

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

main(){
  ListNodePtr startPtr = NULL;
  char item;
  int noOfNodes = 0;
  printf("Write data: ");
  scanf("\n%c",&item);
  while (item != 'q')    {
      push(&startPtr, item);
      printf("Write data: ");
      scanf("\n%c",&item);
      noOfNodes ++;    }
  printf("%d\n", noOfNodes);
  printf("The contents of the stack: \n");
  printList(startPtr);}

% gcc main.c stack.c -o runme
```

## Appendix: Encouraging good coding

Techniques for achieving good coding practices (in a project)

- Assign two people to every part of the project
- Review every line of code
- Require code sign-offs
- Emphasize that code listings are public assets
- Reward good code

(Code Complete: A practical handbook of software construction, Steve McConnell)