

CSCI131

Introduction to Computer Systems

Task Group 4: Libraries and the build process

Complete the exercises, and try to get them marked, before attempting the assignment!

There are several exercise tasks in this task group as detailed below. At the end of this document there is a link to the assignment. You should try to complete all the exercise tasks before attempting the assignment task.

These tasks provide a little more experience in the use of libraries, and with the build process using “make”.

Task 1: More or less ‘standard libraries’ – gd and gdbm: 3 marks

For this task, you simply copy my example code for manipulating data records in a “dbm” style ‘database’. The example also uses the gd graphics library along with some functions to “base-64” encode data. You will build the example first in NetBeans; when it works, you will recreate it using your own ‘makefile’.

dbm libraries

“The dbm library was a simple database engine, originally written by Ken Thompson and released by AT&T in 1979. The name is a three letter acronym for DataBase Manager, and can also refer to the family of database engines with APIs and features derived from the original dbm.” (So says Wikipedia)

A “dbm” database is simple. There are many records in a disk file; each is characterised by a unique primary key. There are no other indexes. Records are just blocks of bytes; a dbm system doesn’t interpret them in any way. You cannot search for records where fields have specific values. All you can do is store and retrieve complete records. But, a dbm system will be fast – lots faster than a relational database such as MySQL.

Most current implementations seem to stem from Berkeley DB – a software package that was released ~1986 as part of the BSD Unix variant. On Ubuntu, the current implementation is via the gdbm library.

gdbm

The gdbm library includes the following functions (details suppressed until later):

`gdbm_open (...)`

`gdbm_close (...)`

Open and close a program’s connection to a gdbm database.

gdbm_store (...)

gdbm_fetch (...)

Store and retrieve keyed records.

gdbm_exists (...)

Check if there is a record matching a specified key.

gdbm_delete (...)

Delete a record identified by a key.

gdbm_firstkey (...)

gdbm_nextkey (...)

These functions allow a program to iterate through all keys (in some random order).

gdbm_reorganize (...)

Programs that create and delete records at a high frequency should occasionally call “reorganize”; the gdbm code will tidy up its disk file reclaiming space used by deleted records.

gdbm_sync (...)

Effectively a flush operation; make sure all changes have been written to disk.

gdbm_strerror (...)

Many of the gdbm calls will return an integer error code when something fails; strerror converts this error code to a message.

gdbm_setopt (...)

gdbm_fdesc (...)

These are for use by specialists. The setopt method allows control of aspects of caching etc. The fdesc method returns the “file descriptor” used to access the file; this might be needed if you wanted to try to lock the file to prevent concurrent updates by different processes.

Gdbm files are not sparse like those illustrated in an earlier exercise.

gd library

“The GD Graphics Library is a graphics software library by Thomas Boutell and others for dynamically manipulating images. Its native programming language is ANSI C, but it has interfaces for many other programming languages.” (So says Wikipedia)

The gd code is widely used (from C, C++, PHP, Python, Perl, ...). The documentation isn’t great; T Boutell lost interest long ago and now it is maintained by Pierre Joye and others who are primarily interested in its use as a graphics library for PHP. Sometimes, it’s easiest to read the PHP documentation!

The use in this example is limited. The program will read in an image from a file (.gif, .jpg, .png formats). It scales the image. The scaled image is converted to .jpg format. The data are then “base64” encoded into a text string that can be added to the database, and gets used directly when displaying a picture in a generated HTML page.

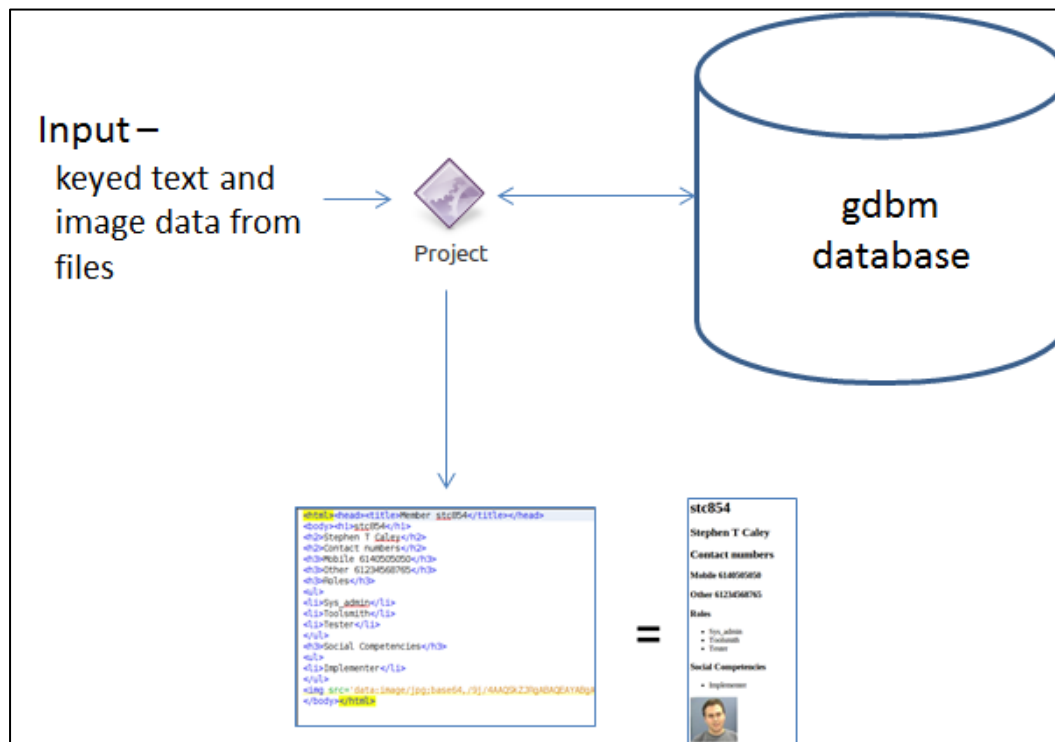
base64

Functions to encode binary data into base64 text strings, and decode base64 text string to retrieve the original binary data, should be part of some standard C library. Base64 text strings have had an important role in encoding data since at least the early 1990s – e.g. they are used when adding data to email.

But there are no standard base64 functions. Apache, and others have published versions of the code on the Internet. We will be using the versions from polarssl.org. The files [base64.h](#) and [base64.c](#) are in the Resources folder on the web site.

Application

The contrived application is for keeping records of members of a project group – user-ids, names, contact numbers, role in project, social competencies. (*Role in project? Social Competencies? You will learn more about project work in CSCI222.*) The application allows for records to be entered, and can on demand create “pretty” HTML pages with details of members.



Use

Typical “menu select” loop (you must have done things like this in CSCI114):

```
Processing options:
0 => Quit; 1 => Add data; 2 => Generate member page; 3 => List members
Opt>1
Enter member details:
```

Entering data

Supply details of project group member:


```
Opt>1
Enter member details:
Family name   : Caley
Given name    : Stephen
Initials      : T
Mobile #      : 6140505050
Other phone # : 61234568765
Unix id       : stc854
Enter roles>?
Choices are:  Manager
              Sys_admin
              Dbadmin
              Webmaster
              Librarian
              Leadprogrammer
              Designer
              UMLArtist
              Programmer
              Documenter
              Toolsmith
              Tester
              Versionmanager
              Pizza_boy
>Sys_admin
>Toolsmith
>Tester
>-
Enter competencies>?
Choices are:  Originator
              Coordinator
              Driver
              Monitor
              Implementer
```

Get list of all project group members:

```
Opt>3
wcl666
ctc333
stc854
dwp395
```

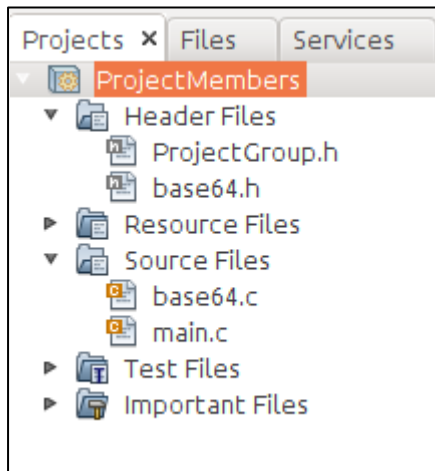
Pick a member and generate a HTML output file that can be viewed in a browser:

```
Opt>2
Enter id : stc854
Enter ID
```

<pre><html><head><title>Member stc854</title></head> <body><h1>stc854</h1> <h2>Stephen T Caley</h2> <h2>Contact numbers</h2> <h3>Mobile 6140505050</h3> <h3>Other 61234568765</h3> <h3>Roles</h3> Sys_admin Toolsmith Tester <h3>Social Competencies</h3> Implementer <img src='data:image/jpeg;base64,/9j/4AAQSkZJRgABAQEAyABg </body></html></pre>	<p>stc854</p> <p>Stephen T Caley</p> <p>Contact numbers</p> <p>Mobile 6140505050</p> <p>Other 61234568765</p> <p>Roles</p> <ul style="list-style-type: none">• Sys_admin• Toolsmith• Tester <p>Social Competencies</p> <ul style="list-style-type: none">• Implementer 
---	---

NetBeans project

Create a new NetBeans project:



The files “base64.h” and “base64.c” should be downloaded from the Resources section of the CSC131 web site (create files base64.h and base64.c in NetBeans and paste in the downloaded code). The header file ProjectGroup.h simply contains a struct declaration. All the application specific code is in main.c

ProjectGroup.h

This contains the struct declaration:

```
#define NAMELENGTH 32
#define INITIALENGTH 4
#define PHONENUMLEN 16
#define USERIDLEN 12

struct projectgroupmemeber {
    char familyname[NAMELENGTH];
    char givenname[NAMELENGTH];
    char initials[INITIALENGTH];
    unsigned int roles;
    unsigned int social;
    char mobile[PHONENUMLEN];
    char other[PHONENUMLEN];
    char uname[USERIDLEN];
};

typedef struct projectgroupmemeber Member;
```

The unsigned int fields “roles”, and “social” will be used as bit-maps. Each project group member will be expected to fill several roles, e.g. “Documenter”, “Toolsmith”, and will profess a number of social competencies, e.g. “Coordinator”, “Finisher”. Bits set in the unsigned int fields will identify the assigned roles and competencies.

The “uname” field is for the member’s unix-id (email-id). This value will also be used as the key for the dbm key-value database.

main.c

```
# WIDTH
addData()
closeDB()
competencies
convert(gdImagePtr im)
databaseconnection
databasename
findCompetency(char* data)
findRole(char* data)
generatePage()
getCompetencies(Member* mptr)
getRoles(Member* mptr)
getScaledImage()
initialiseDB()
listMembers()
loadImage(char* filename, char* filetype)
main(int argc, char** argv)
menuselectloop()
ncompetencies
nroles
printBits(FILE* output, int value, char** names)
printRolesAndCompetencies(FILE* output, Member* mptr)
rolenames
saveData(Member* mptr, gdImagePtr im)
scaleImage(gdImagePtr im)
```

```

44  ⊕ static int findCompetency(char* data) {...7 lines }
51
52  ⊕ static int findRole(char* data) {...7 lines }
59
60  ⊕ static void getRoles(Member* mptr) {...26 lines }
86
87  ⊕ static void getCompetencies(Member* mptr) {...26 lines }
113
114 ⊕ static gdImagePtr loadImage(char* filename, char* filetype) {...22 lines }
136
137 ⊕ static gdImagePtr scaleImage(gdImagePtr im) {...8 lines }
145
146 ⊕ static gdImagePtr getScaledImage() {...30 lines }
176
177 ⊕ static char* convert(gdImagePtr im) {...24 lines }
201
202 ⊕ static void saveData(Member* mptr, gdImagePtr im) {...46 lines }
248
249 ⊕ static void addData() {...25 lines }
274
275 ⊕ static void printBits(FILE* output, int value, char** names) {...14 lines }
289
290 ⊕ static void printRolesAndCompetencies(FILE* output, Member* mptr) {...12 lines }
302
303 ⊕ static void generatePage() {...56 lines }
359
360 ⊕ static void listMembers() {...15 lines }
375
376 ⊕ static void menuselectloop() {...15 lines }
391
392 ⊕ static void initialiseDB() {...16 lines }
408
409 ⊕ static void closeDB() {...3 lines }
412
413 ⊕ int main(int argc, char** argv) {...6 lines }

```

includes

```

#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <gd.h>
#include <gdbm.h>
#include <math.h>
#include <ctype.h>
#include "base64.h"
#include "ProjectGroup.h"

```

All the libraries used are in /usr/include; so in this example there is no need to provide additional “build meta-data” telling the compiler where to find the header files. (Of course, the linker will have to be told to link with the extra libraries; this will be illustrated later.)

Main and menuselectloop

```
static void menuselectloop() {
    printf("Processing options:\n");
    printf("0 => Quit; 1 => Add data; 2 => Generate member page; 3 => List members\n");
    for (;;) {
        printf("Opt>");
        int choice;
        int n = scanf("%d", &choice);
        if ((n != 1) || (choice == 0)) break;
        if (choice == 1) addData();
        else
            if (choice == 2) generatePage();
        else
            if (choice == 3) listMembers();
    }
}

static void initialiseDB() { ...16 lines }

static void closeDB() { ...3 lines }

int main(int argc, char** argv) {
    initialiseDB();
    menuselectloop();
    closeDB();
    return (EXIT_SUCCESS);
}
```


database

A dbm database is simply a file in your directory. You give it some filename (there are no restrictions on the name, there is no requirement for a specific suffix like 'dbm'). When you "open" a connection you get back a pointer type `GDBM_FILE` (it is a typedef type). Typically, this pointer is used as quasi-global variable accessed in all the functions of your application.

```
#include <math.h>
#include "ProjectGroup.h"

#define WIDTH 100

static char* databasename = "Members.dbm";
static GDBM_FILE databaseconnection;
```

There are several parameters for the `gdbm_open()` function. The code provided illustrates standard use; things get a bit more complex if you need to have a gdbm database that can be accessed concurrently by different process.

```
static void initialiseDB() {
    int initialblocksize = 0; // Let system pick blocksize
    // Always create new database
    // int flags = GDBM_NEWDB;

    // Create database if not already in existence
    int flags = GDBM_WRCREAT;

    // mode - same as octal code for chmod
    // want owner read/write; nothing for anyone else
    int mode = 0600;

    // Not providing customized error handler routine so 5th arg is NULL
    databaseconnection = gdbm_open(databasename,
    // ...
    initialblocksize, flags, mode, NULL);
}

static void closeDB() {
    gdbm_close(databaseconnection);
}
```

listmembers

```
Opt>3
wcl666
ctc333
stc854
dwp395
```

You should start by implementing the code to *create a new member record*, and the code to *list the members*. Listing is simpler to explain, so here is that code first.

Dbm libraries will offer functions that provide access to the keys of all records currently in the database. With gdbm, you have the `gdbm_firstkey` and `gdbm_nextkey` functions. These can be used in a function that iterates through all keys, such as the following:

```
static void listMembers() {
    // Have keys for member records - Unix ids, e.g. ead432
    // and keys for image records, e.g. ead432_image
    // Just list the member keys
    datum akey;
    akey = gdbm_firstkey(databaseconnection);
    while(akey.dptr!=NULL) {
        char id[128]; // Caution akey.dptr not nul terminated!
        memset(id,0,128);
        strncpy(id, akey.dptr,akey.dsize);
        char* imagesuffix = strstr(id,"_image");
        if(imagesuffix==NULL)
            printf("%s\n", id);
        datum nkey=gdbm_nextkey(databaseconnection,akey);
        free(akey.dptr);
        akey=nkey;
    }
}
```

Struct `datum` is defined by the `gdbm` library. The following description is from <http://www.vivtek.com/gdbm/api.html>

datum

The `datum` is a simple structure:

```
typedef struct {
    char *dptr;
    int dsize;
} datum;
```

It's used to pass keys and data back and forth from all functions in `gdbm`. Note that this means you're not dependent on the null terminator, but for ease of use, many programs still include the null terminator in keys and data. If your program must interact with others, be sure you understand whether the others are including those terminators or not.

Each key gets returned by filling in the values in the datum akey variable. Gdbm treats the key, which in our case the characters of a unix id, as a block of bytes. It will allocate a block of bytes using malloc, and copy the characters into this block – but does not add a null terminator. The size of the block is set in akey.dsize. The code here has to be careful to create a null terminated string before printing the value of the key.

Since the loop invokes malloc each time, it must also invoke free.

Why “char*”? Dbm really wants “**pointer to bytes**”.

There is no “byte” type in C. So, dbm uses “char*”. Many other libraries also require “pointer to bytes”. Some library authors prefer to use “unsigned char*” as a way of flagging that the data really are not part of a string.

So you get some libraries where all the function signatures all use “char*”, and other libraries where the signatures have “unsigned char*”. Then you have to write code using both libraries – so you pick one style and pass the pointers around.

If the compiler is set at its most pedantic warning style, it will grumble about non-matching data types. But there shouldn’t be any real problems resulting from mixing “char*” and “unsigned char*”.

Creating records

```
static int findCompetency(char* data) {...7 lines }
static int findRole(char* data) {...7 lines }
static void getRoles(Member* mptr) {...26 lines }
static void getCompetencies(Member* mptr) {...26 lines }
static gdImagePtr loadImage(char* filename, char* filetype) {...22 lines }
static gdImagePtr scaleImage(gdImagePtr im) {...8 lines }
static gdImagePtr getScaledImage() {...30 lines }
static char* convert(gdImagePtr im) {...24 lines }
static void saveData(Member* mptr, gdImagePtr im) {...46 lines }
static void addData() {...25 lines }
```

The main function in this group is addData. This function will prompt for the names of the additional member, then invoke auxiliary functions to get “roles” and “competencies”, and to load any image data.

addData

```
249 static void addData() {
250     Member amember;
251     gdImagePtr im;
252     memset(&amember, 0, sizeof (Member));
253     printf("Enter member details:\n");
254     // Careless - not checking for name length limits
255     printf("Family name   : ");
256     scanf("%s", amember.familyname);
257     printf("Given name    : ");
258     scanf("%s", amember.givenname);
259     printf("Initials      : ");
260     scanf("%s", amember.initials);
261     printf("Mobile #       : ");
262     scanf("%s", amember.mobile);
263     printf("Other phone # : ");
264     scanf("%s", amember.other);
265     printf("Unix id        : ");
266     scanf("%s", amember.uname);
267     getRoles(&amember);
268     getCompetencies(&amember);
269     im = getScaledImage();
270     saveData(&amember, im);
271     if(im!=NULL)
272         gdFree(im);
273 }
```

Roles and competencies

```
static char* rolenames[] = {
    "Manager ", "Sys_admin",
    "Db", "Webmaster",
    "Librarian", "Leadprogrammer",
    "Designer", "UMLArtist",
    "Programmer", "Documenter",
    "Toolsmith", "Tester",
    "Versionmanager ", "Pizza_boy"
};

static int nroles = sizeof (rolenames) / sizeof (char*);

static char* competencies[] = {
    "Originator", "Coordinator",
    "Driver", "Monitor",
    "Implementer", "Supporter",
    "Investigator", "Finisher",
    "Chief", "Procrastinator"
};

static int ncompetencies = sizeof (competencies) / sizeof (char*);

static int findCompetency(char* data) {...7 lines }

static int findRole(char* data) {...7 lines }

static void getRoles(Member* mptr) {...26 lines }

static void getCompetencies(Member* mptr) {...26 lines }
```

The code for handling roles and competencies is similar. Only the “role” code is shown here.

The code involves a loop that repeatedly prompts for another role name. The loop terminates if the user enters “-”. If the user enters “?”, the known roles are listed.

The value (string) entered by the user is checked against the set of known roles. If the user mistypes something, or enters a made up role, the entry will be ignored.

Otherwise, the role number is identified and used to set a bit in the bit map “unsigned int roles”.

The code for “competencies” differs only in prompts and the array data used to check inputs.

```

static int findRole(char* data) {
    int i;
    for (i = 0; i < nroles; i++) {
        if (0 == strcmp(data, rolenames[i])) return i;
    }
    return -1;
}

static void getRoles(Member* mptr) {
    printf("Enter roles");

    for (;;) {
        char instr[128];
        printf(">");
        scanf("%s", instr);
        if (0 == strlen(instr)) continue;
        if (instr[0] == '-') break;
        if (instr[0] == '?') {
            int j;
            printf("Choices are:");
            for (j = 0; j < nroles; j++)
                printf("\t%s\n", rolenames[j]);
            continue;
        }
        int ndx = findRole(instr);
        if (ndx < 0) {
            printf("Unrecognized input %s\n", instr);
            printf("Enter role name, or ? to list names, or - to terminate\n");
            continue;
        }
        int bit = 1 << ndx;
        mptr->roles |= bit;
    }
}

```

Image data

```
static gdImagePtr loadImage(char* filename, char* filetype) {...22 lines }  
  
static gdImagePtr scaleImage(gdImagePtr im) {...8 lines }  
  
static gdImagePtr getScaledImage() {...30 lines }
```

If a photo of a group member is available, the program will load the image data from a file, and then scale the image to a standard size.

The getScaledImage function allows the user to indicate whether an image is to be loaded and, if appropriate, provide a filename for that image. The file must be in one of the standard image formats – gif, jpg, png; the format being identified by a file suffix.

```
static gdImagePtr getScaledImage() {  
    char input[128];  
    printf("Is an image available (y|n) : ");  
    scanf("%s", input);  
    if (input[0] != 'y')  
        return NULL;  
  
    char filetype[6];  
    char filename[128];  
  
    printf("Name of image file : ");  
    scanf("%s", filename);  
    char* typesuffix = strrchr(filename, '.');  
    if (typesuffix == NULL) {  
        printf("No filetype suffix?\n");  
        printf("Ignoring request of image\n");  
        return NULL;  
    }  
    strcpy(filetype, typesuffix + 1);  
    char *p;  
    for (p = filetype; *p != '\0'; p++)  
        *p = (char) tolower(*p);  
    gdImagePtr im = loadImage(filename, filetype);  
    gdImagePtr ims = scaleImage(im);  
    gdImageDestroy(im);  
  
    return ims;  
}
```

Loading an image is straightforward using the functions from the gd graphics library:

```

static gdImagePtr loadImage(char* filename, char* filetype) {
    FILE *afile;
    afile = fopen(filename, "r");
    if (afile == NULL) {
        perror("File failed to open");
        exit(1);
    }
    gdImagePtr im = NULL;
    if (0 == strcmp(filetype, "gif")) {
        im = gdImageCreateFromGif(afile);
    } else
        if (0 == strcmp(filetype, "png")) {
            im = gdImageCreateFromPng(afile);
        } else
            if ((0 == strcmp(filetype, "jpg")) || (0 == strcmp(filetype, "jpeg"))) {
                im = gdImageCreateFromJpeg(afile);
            } else {
                printf("Sorry - cannot handle image type %s\n", filetype);
            }
    fclose(afile);
    return im;
}

```

An image will be a complex data structure created in the heap; there is a primary “image” structure (this is identified by the pointer returned). There may be other structures such as colour palettes that are also created. Code should always free the space for images that are no longer required by using the `gdImageDestroy()` function; other structures created by gd should be freed using `gdFree()` (don’t simply call `free()`).

The gd library provides several functions to scale images. They differ in how details of the new image are calculated; these differences are only important in more advanced use. A simple scaling function is as follows:

```

static gdImagePtr scaleImage(gdImagePtr im) {
    int w = gdImageSX(im);
    int h = gdImageSY(im);

    int nh = (int) ceil(WIDTH * h / w);
    gdImagePtr ims = gdImageScale(im, WIDTH, nh);
    return ims;
}

```

The functions `gdImageSX` and `gdImageSY` return the width and height of an image.

Saving data

```
static char* convert(gdImagePtr im) {...24 lines }  
  
static void saveData(Member* mptr, gdImagePtr im) {...46 lines }
```

Once data for a new member have been entered, they must be saved to the gdbm database. The same database (dbm file) is going to be used to store both member records, and image data. Member records will be stored with keys that are the member's unix-ids, e.g. ead432. Images will be stored with keys like ead432_image. (Dbm systems don't care about the data – they are just a block of bytes. So there are no problems with storing different types of data record in the one file.)

The image data could be saved as they exist in memory as the scaled image record (i.e. a pixel array). But when they get used for generating HTML pages, they have to be as a base-64 encoded version of a standard image format such as jpg. So here the program does the conversion to jpeg encoding and base-64 conversion prior to storing the image.

convert

The conversion function first generates an array of bytes with the .jpg format representation of the image. (This uses gdImageJpegPtr a listed but undocumented function in the gd library). This array of bytes is then encoded in base-64.

```
static char* convert(gdImagePtr im) {  
    // Convert the image to jpeg, default quality, getting  
    // back pointer to allocated bytes and length  
    int size;  
    void* jpegbytes = gdImageJpegPtr(im, &size, 75);  
  
    size_t encodedsize = 0;  
    unsigned char* source = (unsigned char*) jpegbytes;  
    char* b64codes = NULL;  
    // Invoke base64 encoder first time just to get length of  
    // base 64 string  
    base64_encode(b64codes, &encodedsize, source, size);  
    // Allocate space  
    b64codes = malloc(encodedsize + 1);  
    // Convert  
    int res = base64_encode(b64codes, &encodedsize, source, size);  
  
    gdFree(jpegbytes);  
  
    if (res != 0) {  
        printf("Failed to base 64 encode data\n");  
        if (b64codes != NULL)  
            free(b64codes);  
        return NULL;  
    }  
    return b64codes;  
}
```

saveData

The saveData function is a bit long, so first we have the main code for saving the member record (with the code to save the image hidden in an “editor-fold”).

```
202 static void saveData(Member* mptr, gdImagePtr im) {
203     datum key;
204     datum value;
205
206     char* keyv = strdup(mptr->uname);
207     int keylen = strlen(keyv);
208
209     key.dptr = keyv;
210     key.dsize = keylen;
211
212     value.dptr = (char*) mptr;
213     value.dsize = sizeof(Member);
214     // Allow overwriting of records
215     // So if entry exists with key it will be replaced
216     int res = gdbm_store(databaseconnection,
217         key, value, GDBM_REPLACE );
218     if(res!=0) {
219         printf("Failed to store record for %s\n",keyv);
220     }
221     else {
222         printf("Stored record for %s\n",keyv);
223         saving image data
247     }
248     free(keyv);
249 }
```

Two datum structures have to be used; one is for the key, the other is for the value. Each datum has a pointer to bytes member, and a length.

The gdbm_store function is used to write the key/value combination to file.

The code that stores a record for image data is similar:

```

if(res!=0) {
    printf("Failed to store record for %s\n",keyv);
}
else {
    printf("Stored record for %s\n",keyv);
    //<editor-fold desc="saving image data">
    if(im!=NULL) {
        char* imageastr = convert(im);
        char otherkey[128];
        strcpy(otherkey,keyv);
        strcat(otherkey,"_image");
        datum imagekey;
        datum imagedata;

        imagekey.dptr = otherkey;
        imagekey.dsize = strlen(otherkey);

        imagedata.dptr = imageastr;
        imagedata.dsize = strlen(imageastr);

        int ires = gdbm_store(databaseconnection,
            imagekey, imagedata,GDBM_REPLACE );

        if(ires!=0)
            printf("\t(but failed to store image)\n");

        free(imageastr);
    }
    //</editor-fold>
}
free(keyv);
}

```

Output

The program has to generate HTML pages that can be viewed in a browser. This is simply a matter of retrieving the required record and then taking values from the record and slotting them into standard HTML markup text.

Opt>2
Enter id : stc854
Opt>2


```
<html><head><title>Member stc854</title></head>
<body><h1>stc854</h1>
<h2>Stephen T Caley</h2>
<h2>Contact numbers</h2>
<h3>Mobile 6140505050</h3>
<h3>Other 61234568765</h3>
<h3>Roles</h3>
<ul>
<li>Sys_admin</li>
<li>Toolsmith</li>
<li>Tester</li>
</ul>
<h3>Social Competencies</h3>
<ul>
<li>Implementer</li>
</ul>
<img src='data:image/jpg;base64,/Sj/4AAQSkZJRgABAQEA...'/>
</body></html>
```

stc854
Stephen T Caley
Contact numbers
Mobile 6140505050
Other 61234568765
Roles

- Sys_admin
- Toolsmith
- Tester

Social Competencies

- Implementer



Output is via the generatePage function along with two auxiliary functions that create HTML lists from the data in the roles and competencies fields of a user record.

```
static void printBits(FILE* output,int value, char** names) {...14 lines }
static void printRolesAndCompetencies(FILE* output, Member* mptr) {...12 lines }
static void generatePage() {...56 lines }
```

generatePage

The generatePage function constructs a datum for the key based on the entered user-id, and uses this to retrieve a member record (returning with no output if there is no record for that key). It then tries to load an associated image record.

The output file is opened.

The HTML is generated by the code that is hidden in the editor-fold in the following view:

```

static void generatePage() {
    printf("Enter id : ");
    char id[128];
    scanf("%s", id);

    datum query;
    query.dptr = id;
    query.dsize = strlen(id);

    datum data = gdbm_fetch(databaseconnection, query);
    if (data.dptr == NULL) {
        printf("There is no record for key %s\n", id);
        return;
    }
    Member* amember = (Member*) data.dptr;

    // Try for image
    strcat(id, "_image");
    query.dptr = id;
    query.dsize = strlen(id);
    datum imagedata = gdbm_fetch(databaseconnection, query);

    char outputfilename[128];
    strcpy(outputfilename, amember->uname);
    strcat(outputfilename, ".html");

    FILE* output = fopen(outputfilename, "w");
    if (output == NULL) {
        printf("Unable to create an output file\n");
        // Need to free space anyway
        free(data.dptr);
        if (imagedata.dptr != NULL)
            free(imagedata.dptr);
    }
    html output
    fclose(output);
    free(data.dptr);
    if (imagedata.dptr != NULL)
        free(imagedata.dptr);
}

```

The HTML code is largely fixed - <head> section, <body> etc. Details from the member record are slotted into <h1>...</h1> fields etc.

The roles and competencies will be lists; the code is shown later.

Commonly, an image in a HTML page is encoded as an tag with a src attribute that is the URL of the image (or sometimes is the URL of a program that will generate an image).

But if an image is small, it is better to have the HTML code contain the actual image data (this saves on HTTP traffic). Images can be defined as data strings that are given directly in an tag. This is done here with the base-64 encoded image data from the gdbm database. (Again, it is necessary to deal with a string that is not nul terminated; an unusual printf format string is used to select and print the correct number of characters in the base-64 string.)

```

//<editor-fold desc="html output">
fprintf(output, "<html><head><title>Member %s</title></head>\n", amember->uname);
fprintf(output, "<body><h1>%s</h1>\n", amember->uname);
fprintf(output, "<h2>%s %s %s</h2>\n", amember->givenname, amember->initials, amember->familyname);
fprintf(output, "<h2>Contact numbers</h2>\n<h3>Mobile %s</h3>\n<h3>Other %s</h3>\n",
    amember->mobile, amember->other);
printRolesAndCompetencies(output, amember);

if (imagedata.dptr != NULL) {
    fprintf(output, "<img src='";
    fprintf(output, "data:image/jpeg;base64,");
    // Again caution, not null terminated string
    // rather than copying actual content, try using length
    fprintf(output, "%*.s", imagedata.dsize, imagedata.dsize, imagedata.dptr);

    fprintf(output, "' />\n");
}
fprintf(output, "</body></html>");
//</editor-fold>

```

printBits and printRolesAndCompetencies

These functions are used to convert data in the bit-map integers into HTML lists.

```

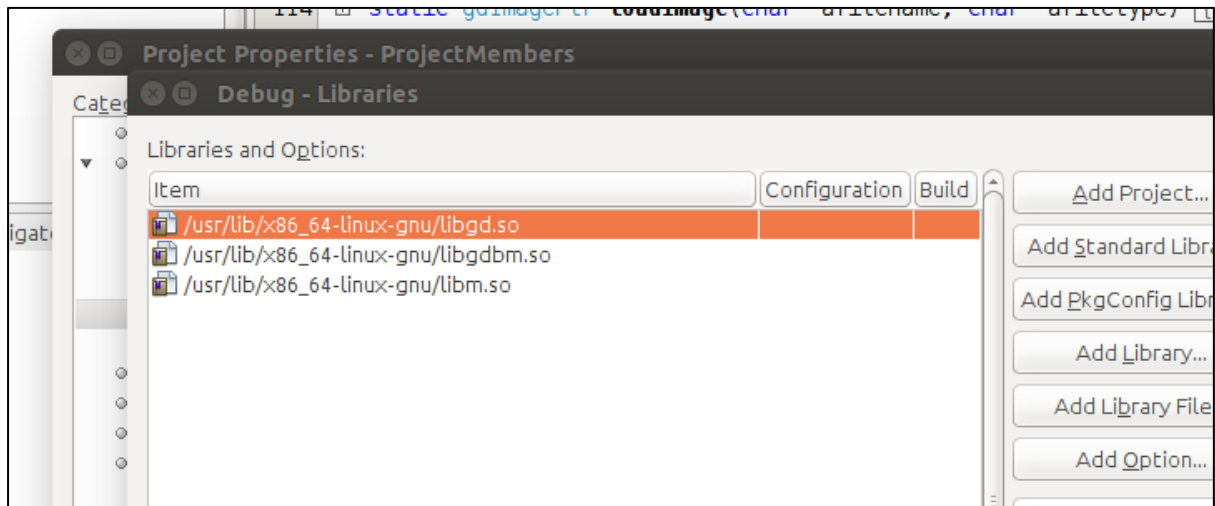
static void printBits(FILE* output, int value, char** names) {
    int i = 0;
    int bit = 1;
    fprintf(output, "<ul>\n");
    for(i=0; i<32; i++) {
        int tst = value & bit;
        bit = bit << 1;
        if(tst) {
            fprintf(output, "<li>%s</li>\n", names[i]);
        }
    }
    fprintf(output, "</ul>\n");
}

static void printRolesAndCompetencies(FILE* output, Member* mptr) {
    int roles = mptr->roles;
    if(roles!=0) {
        fprintf(output, "<h3>Roles</h3>\n");
        printBits(output, roles, rolenames);
    }
    int social = mptr->social;
    if(social!=0) {
        fprintf(output, "<h3>Social Competencies</h3>\n");
        printBits(output, social, competencies);
    }
}

```

Linking

Both gdbm and gd should be in /usr/lib. But the linker must still be told to search these libraries. In your NetBeans project, you should use the Project/Properties/Linker dialog to specify the libraries ("Add Library File").

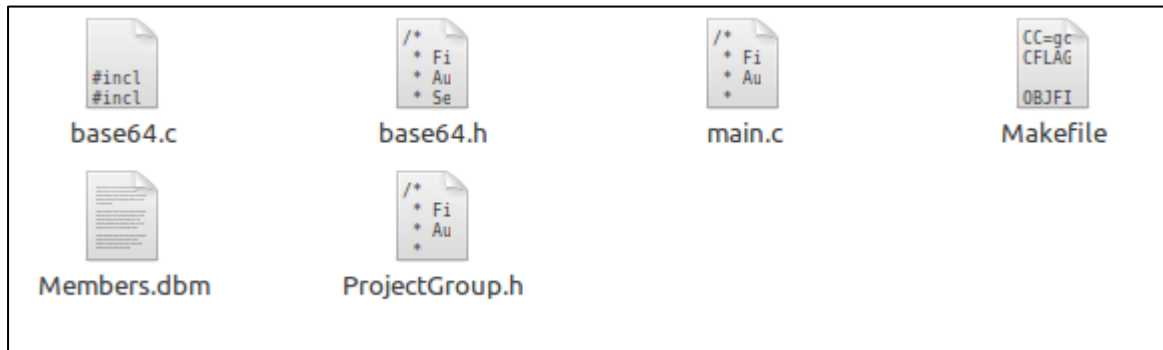


The libraries will be in the 64-bit subdirectory of /usr/lib.

No IDE

When you have got the program to run correctly within NetBeans, you should create a copy that will be built using your own makefile.

Create a new subdirectory, and copy into this directory the files main.c, ProjectGroup.h, base64.h, base64.c along with any Members.dbm file that you have generated.



makefile

```
CC=gcc
CFLAGS=-Wall -g

OBJFILES=main.o base64.o
LIBRARYFILES=-lgdbm -lgd -lm

Project: $(OBJFILES)
    $(CC) -o Project $(OBJFILES) $(LIBRARYFILES)

clean:
    rm -f Project *.o *.html *~

main.o:base64.h ProjectGroup.h
base64.o:base64.h
```

CC=gcc

Use the gcc compiler

CFLAGS=-Wall -g

Make the compiler warn about all possible errors, and add in debugging information.

OBJFILES=main.o base64.o

The generated code files needed to build the program are main.o, and base64.o. These will be generated in accord with default rules from main.c and base64.c

LIBRARYFILES=-lgdbm -lgd -lm

Build with the appropriate versions of these libraries. Here, the libraries are being specified using the conventional syntax with “-l”. The linker will look for files libgdbm.so etc. (It will use configuration data that makes it check for 64-bit versions of the code.)

(NetBeans uses absolute path names for library files, but that isn’t conventional for Unix programmers.)

There are two targets – Project, and clean (technically, clean is a pseudo target).

Project: \$(OBJFILES)

\$(CC) -o Project \$(OBJFILES) \$(LIBRARYFILES)

The target Project should be built if the file “Project” does not exist or if it is older than any of the files identified in the file list OBJFILES (or files that these depend on).

Use the build toolkit specified by value of \$(CC) to compile and link the code with output to “Project”.

clean:

rm -f Project *.o *.html *~

Target clean doesn’t have any dependencies. It will always run when asked for.

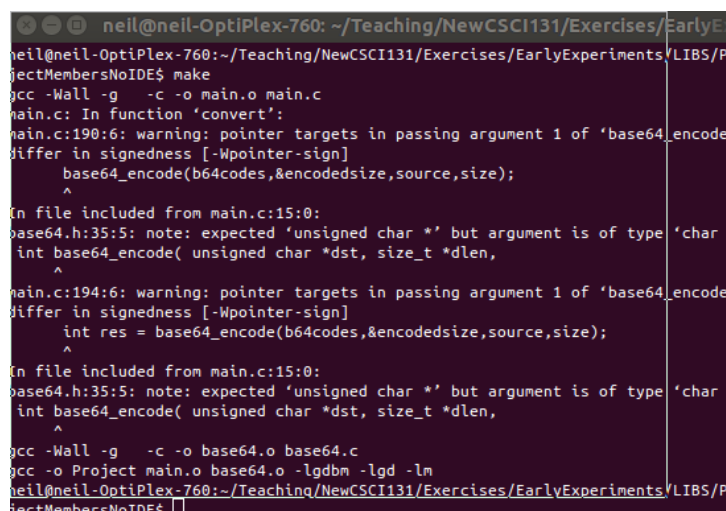
It removes the listed files – Project, any files with type .o, any .html files (outputs from earlier tests) and any files ending in ~ (discarded files from editors). You could also specify “.dbm” if you wanted to clear out database files.

main.o:base64.h Project.h

base64.o:base64.h

These specify extra dependencies. If either header file is changed, main.c must be recompiled. (The dependency specifies main.o not main.c. The make program cannot build main.c! It has to recreate the compiled version.)

Try building with your makefile (the compiler should grumble about the mixing of char* and unsigned char*).

A terminal window showing the execution of a make command. The prompt is 'neil@neil-OptiPlex-760: ~/Teaching/NewCSCI131/Exercises/EarlyExperiments/LIBS/P'. The output shows the compilation of main.c into main.o with warnings about pointer targets and signedness. Then, base64.c is compiled into base64.o with similar warnings. Finally, the two object files are linked into the 'Project' executable using gcc, with flags -Wall, -g, -c, -o, -lgdbm, -lzd, and -lm. The final prompt is 'neil@neil-OptiPlex-760: ~/Teaching/NewCSCI131/Exercises/EarlyExperiments/LIBS/P'.

The program should run.

Try make again. The make program should reply that it has nothing to do as everything is up to date.

Try “touch Project.h”. That should change the date on the Project.h file. Try make again. It should re-build the application.

Clean up with “make clean”.

Task 2: Redis client library: 3 marks

This exercise uses an unusual library – the C/C++ client library for the Redis database server.

“Redis is a data structure server. It is open-source, networked, in-memory, and stores keys with optional durability. The development of Redis has been sponsored by Pivotal Software since May 2013; before that, it was sponsored by VMware. According to the monthly ranking by DB-Engines.com, Redis is the most popular key-value store. The name Redis means REmote DIctionary Server.” (So says Wikipedia)

*“Redis is written in ANSI C and works in most POSIX systems like Linux, *BSD, OS X without external dependencies. Linux and OSX are the two operating systems where Redis is developed and more tested, and we recommend using Linux for deploying. Redis may work in Solaris-derived systems like SmartOS, but the support is best effort. There is no official support for Windows builds, but Microsoft develops and maintains a Win-64 port of Redis.” (So says Redis’s own documentation.)*

Redis is one of the “No-SQL” database systems that has emerged post 2005. Generally, these database systems provide more limited functionality than a relational database system such as MySQL, emphasising instead either much faster performance or greater scalability.

Redis keeps its data in memory (which is why it is fast), with regular backups to file. (Redis files are typically stored in /var/lib/redis.)

In the laboratory, the Redis server runs as a standard Linux service; when Linux starts, one of the processes that it creates is the Redis server. The Redis server is accessed via TCP/IP. A client process can run on the same machine (accessing its “localhost” at address 127.0.0.1) or can run on another machine on the network.

Redis has a simple command line client that can be used to practice the storage and retrieval of data. Client libraries exist for a number of programming languages allowing the Redis server to be accessed from applications. The C client code has been installed in the laboratory in /usr/unusual ; there are header files, and linkable library files. (There are several C clients; the one we use is hiredis.) (If you are trying to do the exercises on your own computer, you will have to install the Redis server and command line client, and configure Redis to run as a service. You will also need to install the hiredis C client code).

What is a “data structure server”?

With gdbm, the data stored for a given key are simple a block of uninterpreted bytes. But with Redis the values associated with the keys can be:

- Integers (you can use these as counters that get incremented);
- Strings
- Binary data (unintepreted bytes as in gdbm)
- Lists!
A Redis list value is a collection of strings sorted by insertion order.
- Sets!
A Redis set is a collection of unique strings.

- **Hashes!**
The Redis key will point to a structure that is itself a collection of string key/value pairs.
- (There are additional more exotic structure types).

When using an SQL database, e.g. Oracle or MySQL, from a command line client (e.g. Oracle's sqlplus client) or from within an application you compose strings with SQL commands that are sent to the database server. Work with Redis is similar. **You compose strings containing the data manipulation commands that you wish the Redis server to execute.** When working with the Redis command line client you simply type these commands; in an application, you compose the string with the command and use a library function to send the command to the server and return a data structure with the results.

The full set of commands, with illustrations of their use, is on the web at redis.io/commands:

redis			
Commands Clients Documentation Community Download Issues Support License			
APPEND key value Append a value to a key	DECRBY key offset Returns the bit value at offset in the string value stored at key	PEXPIREAT key milliseconds-timestamp Set the expiration for a key as a UNIX timestamp specified in milliseconds	SHEBERS key Get all the members in a set
AUTH password Authenticate to the server	GETRANGE key start end Get a substring of the string stored at a key	PFAADD key element [element ...] Adds the specified elements to the specified HyperLogLog	SHOVE source destination member Move a member from one set to another
BGREWRITEAOF Asynchronously rewrite the append-only file	GETSET key value Set the string value of a key and return its old value	PFCOUNT key [key ...] Return the approximated cardinality of the sets(s) observed by the HyperLogLog at key(s)	SORT key [BY pattern] [ASC DESC] [LIMIT offset count] [GET pattern [GET pattern ...]] Sort the elements in a list, set or sorted set
BSAVE Asynchronously save the database to disk	HDEL key field [field ...] Delete one or more hash fields	PFMERGE destkey sourcekey [sourcekey ...] Merge N different HyperLogLogs into a single one	SPOP key Remove and return a random member from a set
BITCOUNT key [start end] Count set bits in a string	HEXISTS key field Determine if a hash field exists	PING Ping the server	SRANDMEMBER key [count] Get one or multiple random members from a set
BITOP operation destkey key [key ...] Perform bitwise operations between strings	HGET key field Get the value of a hash field	PISETEX key milliseconds value Set the value and expiration in milliseconds of a key	SREM key member [member ...] Remove one or more members from a set
BITPOS key bit [start] [end] Find first bit set or clear in a string	HGETALL key Get all the fields and values in a hash	PUNSUBSCRIBE pattern [pattern ...] Listen for messages published to channels matching the given patterns	STRLEN key Get the length of the value stored in a key
BLPOP key [key ...] timeout Remove and get the first element in a list, or block until one is available	INCRBY key field increment Increment the integer value of a hash field by the given number	PUBSUB subcommand [argument [argument ...]] Inspect the state of the Pub/Sub subsystem	SUBSCRIBE channel [channel ...] Listen for messages published to the given channels
BRPOP key [key ...] timeout Remove and get the last element in a list, or block until one is available	INCRBYFLOAT key field increment Increment the float value of a hash field by the given amount	PTTL key Get the time to live for a key in milliseconds	SUNION key [key ...] Add multiple sets
BRPOPLPUSH source destination timeout Pop a value from a list, push it to another list and return it, or block until one is available	MGET key Get all the fields in a hash	PUBLISH channel message Post a message to a channel	SUNIONSTORE destination key [key ...] Add multiple sets and store the resulting set in a key
CLIENT KILL [arguments] [ID client-id] [TYPE normal slave master] [ADDR ip:port] Kill the connection of a client	MLEN key Get the number of fields in a hash	PUNSUBSCRIBE pattern [pattern ...] Stop listening for messages posted to channels matching the given patterns	SYNC Internal command used for replication

There are several tutorials available on the web that illustrate Redis's commands.

The following recording shows use of the Linux redis-cli command line client being used to work with simple string, integer, and set data:

```

neil@neil-OptiPlex-760:~$ redis-cli ping
PONG
neil@neil-OptiPlex-760:~$ redis-cli
127.0.0.1:6379> set greeting "hello world"
OK
127.0.0.1:6379> get greeting
"hello world"
127.0.0.1:6379> set count 42
OK
127.0.0.1:6379> incr count
(integer) 43
127.0.0.1:6379> incrby count 56
(integer) 99
127.0.0.1:6379> sadd people1 tom dick harry sue
(integer) 4
127.0.0.1:6379> get greeting
"hello world"
127.0.0.1:6379> smembers people1
1) "sue"
2) "harry"
3) "dick"
4) "tom"
127.0.0.1:6379> sadd people1 bill jane
(integer) 2
127.0.0.1:6379> scard people1
(integer) 6
127.0.0.1:6379> srandmember people1 3
1) "dick"
2) "tom"
3) "jane"
127.0.0.1:6379> sadd people2 jane will pete oscar
(integer) 4
127.0.0.1:6379> sinter people1 people2
1) "jane"
127.0.0.1:6379> sismember people1 tony
(integer) 0
127.0.0.1:6379> sismember people1 tom
(integer) 1

```

The command:

```
redis-cli ping
```

serves to check whether the redis server is running. (If it's running, it will reply pong).

The `redis-cli` command started a client session. The key 'greeting' is assigned the string value "hello world"; the key count is given the value 42. The value of count is incremented in different ways. Then a "set" is created; the set is named 'people1', its initial members are the strings 'tom', 'dick', 'harry', and 'sue'. Different functions are used to retrieve simple data elements, sets, and hashes. There are utility functions like `scard` which gives the number of elements in a set; `srandmember` which selects some number of elements from a set chosen at random; `sinter` which intersects sets; and `sismember` that tests whether an element is currently in a set.

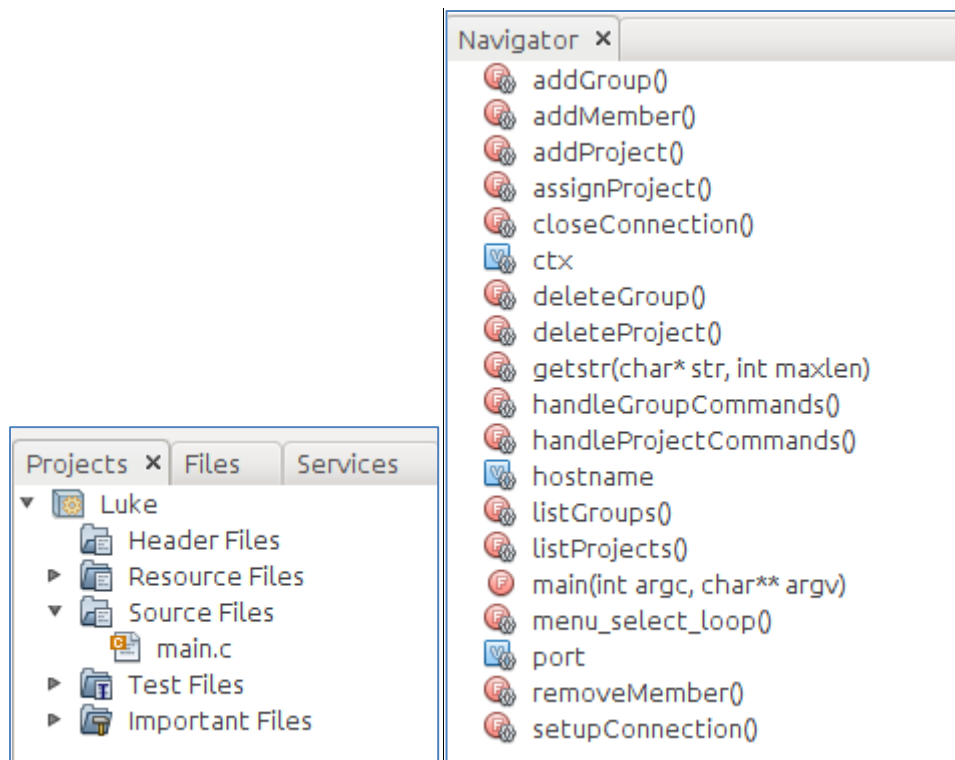
The command line client can be useful when debugging an application that uses Redis. You can use it to visualise the data that have been added. There is a debugging command "keys *" that lists all the keys; you can then use `get`, or `smembers`, or `hgetall` to look at the content of a simple element, a

set, or a hash. (The keys command is not supposed to be used in application code as it is very costly at run-time; it is helpful for debugging).

Application

The contrived application is a simple program that might be useful for the administrator of CSCI321 projects. It is to maintain records of available projects, student groups, and the allocation of projects to groups.

It's built as a NetBeans C application:



Once again, it is a “menu-select” program with commands for dealing with the projects and the student groups:

```

put - Luke (Run)
Connected to redis server
=>?
Commands:
    ? : print this command list
    q : quit
    Restart: re-initialize the database
    Project: sub-commands for project
    Group: sub-commands for group
=>Project
Project=>?
Project Commands:
    ? : print this command list
    q : finish project commands
    Add: Add a project
    Delete: Delete a project
    List: List projects
Project=>List
There are 0 projects currently in the database
Project=>q
=>Group
Groups=>?
Group Commands:
    ? : print this command list
    q : finish group commands
    Add: Create new empty group
    Delete: Delete a group
    List: List groups
    Member: Add member to group
    Remove: Remove member from group
    Assign: Assign project to group
Groups=>List
There are 0 groups currently in the database
Groups=>q
=>

```

The application maintains a collection of projects, with unique application defined identifiers. Each project has a collection of attributes – initially just title, and supervisor.

These data will be represented in the Redis database:

- A counter used to create distinct project identifiers.
- A set with strings that are the project names.
- For each project, there will be a 'hash'; its key is a project name, it will initially have values for two attributes (title, supervisor).

The following record shows some projects being added to the Redis database:

```

=>Project
Project=>Add
Project title : E-auction
Supervisor    : Koren
Project=>Add
Project title : Boom town
Supervisor    : Ian
Project=>Add
Project title : Generalised Image Manipulation using Internet Photo Collection
Supervisor    : Lei Wang
Project=>List
There are 3 projects currently in the database
Project Project:2
Title: Boom town
Supervisor: Ian
Project Project:1
Title: E-auction
Supervisor: Koren
Project Project:3
Title: Generalised Image Manipulation using Internet Photo Collection
Supervisor: Lei Wang
Project=>

```

The application will also keep track of groups and there members. The application allocates unique group identifiers; maintains a set with the names of the groups; each group will have a set of members.

```

Groups=>Member
Adding student to group
Group        : Group:1
Student id   : asx56
Groups=>Member
Adding student to group
Group        : Group:1
Student id   : by42
Groups=>Member
Adding student to group
Group        : Group:1
Student id   : ttl342
Groups=>Add
Groups=>Member
Adding student to group
Group        : Group:2
Student id   : pop87
Groups=>List
There are 2 groups currently in the database
Group Group:1
    Members: by42 ttl342 asx56
Group Group:2
    Members: pop87
Groups=>

```

One can use the redis-cli client to check these data:

```

127.0.0.1:6379> SMEMBERS Projects
1) "Project:2"
2) "Project:1"
3) "Project:3"
127.0.0.1:6379> HGETALL Project:1
1) "Title"
2) "E-auction"
3) "Supervisor"
4) "Koren"
127.0.0.1:6379> get projectcount
"3"
127.0.0.1:6379> get groupcount
"2"
127.0.0.1:6379> SMEMBERS Group:1
1) "by42"
2) "ttl342"
3) "asx56"
127.0.0.1:6379> SMEMBERS Groups
1) "Group:1"
2) "Group:2"
127.0.0.1:6379>

```

Other manipulations can be performed – allocate projects to groups, add and remove members for a group, delete projects:

```

Groups=>List
There are 2 groups currently in the database
Group Group:1
    Members: by42 ttl342 asx56
Group Group:2
    Members: pop87
Groups=>Remove
Removing student from group
Group      : Group:1
Student id : asx56
Groups=>Member
Adding student to group
Group      : Group:2
Student id : asx56
Groups=>List
There are 2 groups currently in the database
Group Group:1
    Members: by42 ttl342
Group Group:2
    Members: asx56 pop87
Groups=>

```



```
=>Project
Project=>List
There are 3 projects currently in the database
Project Project:2
Title: Boom town
Supervisor: Ian
Project Project:1
Title: E-auction
Supervisor: Koren
Group: Group:1
Project Project:3
Title: Generalised Image Manipulation using Internet Photo Collection
Supervisor: Lei Wang
Project=>
```

```
Project=>Delete
Delete project with id : Project:2
Project=>List
There are 2 projects currently in the database
Project Project:1
Title: E-auction
Supervisor: Koren
Group: Group:1
Project Project:3
Title: Generalised Image Manipulation using Internet Photo Collection
Supervisor: Lei Wang
Project=>
```

The Code

It is a typical menu-select program – some initialization, the command loop, and some final tidying up before termination. The commands are at two levels – top level commands selecting whether processing groups or projects, and detailed commands for these two cases.

```

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

#include <hiredis.h>

// Data for the connection to a redis server on the local machine
static char* hostname = "127.0.0.1";
static redisContext *ctx;
static int port = 6379;

static void setupConnection() { ...14 lines }

static void closeConnection() { ...4 lines }

static void getstr(char* str, int maxlen) { ...9 lines }

static void addProject() { ...26 lines }

static void deleteProject() { ...24 lines }

static void ListProjects() { ...32 lines }

static void handleProjectCommands() { ...23 lines }

static void addGroup() { ...14 lines }

static void deleteGroup() { ...23 lines }

static void ListGroups() { ...32 lines }

static void addMember() { ...20 lines }

static void removeMember() { ...20 lines }

static void assignProject() { ...40 lines }

static void handleGroupCommands() { ...32 lines }

static void menu_select_loop() { ...28 lines }

int main(int argc, char** argv) {
    setupConnection();
    menu_select_loop();
    closeConnection();

    return (EXIT_SUCCESS);
}

```

Functions to establish and later close a connection to the Redis server are standard:

```
// Data for the connection to a redis server on the local machine
static char* hostname = "127.0.0.1";
static redisContext *ctx;
static int port = 6379;

static void setupConnection() {
    struct timeval timeout = {1, 500000}; // 1.5 seconds
    ctx = redisConnectWithTimeout(hostname, port, timeout);
    if (ctx == NULL || ctx->err) {
        if (ctx) {
            printf("Connection error: %s\n", ctx->errstr);
            redisFree(ctx);
        } else {
            printf("Connection error: can't allocate redis context\n");
        }
        exit(1);
    }
    printf("Connected to redis server\n");
}

static void closeConnection() {
    redisFree(ctx);
    printf("Disconnected from redis server\n");
}
```

The top-level menu select loop is:

```
static void menu_select_loop() {
    for (;;) {
        printf("=>");
        char command[128];
        getstr(command, 128);
        if (command[0] == 'q') break;
        if (command[0] == '?') {
            printf("Commands:\n");
            printf("\t? : print this command list\n");
            printf("\tq : quit\n");
            printf("\tRestart: re-initialize the database\n");
            printf("\tProject: sub-commands for project\n");
            printf("\tGroup: sub-commands for group\n");
        }
        if (0 == strcmp(command, "Restart")) {
            redisReply *reply;
            // FLUSHDB, or if really want to clear everything from
            // Redis FLUSHALL
            reply = redisCommand(ctx, "FLUSHDB");
            freeReplyObject(reply);
        } else
            if (0 == strcmp(command, "Project"))
                handleProjectCommands();
            else
                if (0 == strcmp(command, "Group"))
                    handleGroupCommands();
    }
}
```

Group commands

Group commands are handled by a subordinate menu-select loop:

```
static void handleGroupCommands() {
    for (;;) {
        printf("Groups=>");
        char command[128];
        getstr(command, 128);
        if (command[0] == 'q') break;
        if (command[0] == '?') {
            printf("Group Commands:\n");
            printf("\t? : print this command list\n");
            printf("\tq : finish group commands\n");
            printf("\tAdd: Create new empty group\n");
            printf("\tDelete: Delete a group\n");
            printf("\tList: List groups\n");
            printf("\tMember: Add member to group\n");
            printf("\tRemove: Remove member from group\n");
            printf("\tAssign: Assign project to group\n");
        }
        if (0 == strcmp(command, "Add")) addGroup();
        else
            if (0 == strcmp(command, "Delete")) deleteGroup();
        else
            if (0 == strcmp(command, "List")) listGroups();
        else
            if (0 == strcmp(command, "Member")) addMember();
        else
            if (0 == strcmp(command, "Remove")) removeMember();
        else
            if (0 == strcmp(command, "Assign")) assignProject();
    }
}
```

When a group is added, the counter in the Redis database must be incremented, and its updated value used to generate a new group identifier. This group identifier must be added to the set of group identifiers as maintained by Redis. This code provides a first view of the hiredis library API for C clients to Redis.

The function `redisCommand()` is used to create and submit commands. The `redisCommand()` function has been made to work a bit like `fprintf`. The `fprintf` function took a `FILE*` connection, a format string, and an arbitrary number of additional arguments; it worked with the low-level I/O system to send text and returned a count of elements successfully sent. The `redisCommand()` function takes a `redisContext` argument (connection to Redis), a format string, and an arbitrary number of additional arguments. It returns a data-structure whose fields hold result data. (This structure will have been allocated on the heap, along with any required subordinate structures such as strings also allocated on the heap. These data must be freed after use using the `freeReplyObject` function.)

In this code, the first command is simple – increment the specified ‘groupcount’ element in the Redis database. (If ‘groupcount’ didn’t exist, it would be created with value 0.)

The second command is a bit more complex, it adds a member to the set “GROUPS”. The value added is a string (%s in the format string). It will be the name generated for the new group.

```
static void addGroup() {
    redisReply *reply;
    reply = redisCommand(ctx, "INCR groupcount");
    int account = (int) reply->integer;
    freeReplyObject(reply);

    char projid[128];
    memset(projid, 0, 128);
    sprintf(projid, "Group:%d", account);

    // Add the project id to the set of all projects
    reply = redisCommand(ctx, "SADD Groups %s", projid);
    freeReplyObject(reply);
}
```

A group may have to be deleted. The code here checks whether the name as entered is a defined member of the set (this is just to catch typing errors made by the user); this code uses the SISMEMBER Redis operation. This should return an integer value, so the appropriate field is checked in the reply object. If a group with the name existed, it is first removed from the set, and then all data associated with that name are removed (if members had been allocated to the group, the Redis database would have contained a set with the groupname as key).

```
static void deleteGroup() {
    char gname[128];

    printf("Delete group with id : ");
    getstr(gname, 128);

    redisReply *reply;
    reply = redisCommand(ctx, "SISMEMBER Groups %s", gname);
    int res = (0 == reply->integer);
    freeReplyObject(reply);

    if (res) {
        printf("There was no group with that id\n");
    } else {
        // Remove id from set
        reply = redisCommand(ctx, "SREM Groups %s", gname);
        // Not checking confirmation, just assume it works
        freeReplyObject(reply);
        // Now remove the group details
        reply = redisCommand(ctx, "DEL %s", gname);
        freeReplyObject(reply);
    }
}
```

The user would need to be able to list groups with their members. Note how here we get an array of string data elements for the identifiers of the members:

```
static void ListGroups() {
    redisReply *reply;
    reply = redisCommand(ctx, "SCARD Groups");

    int count = (int) reply->integer;
    freeReplyObject(reply);
    printf("There are %d groups currently in the database\n",
        count);
    char** groupnames = malloc(count * sizeof(char*));
    reply = redisCommand(ctx, "SMEMBERS Groups");
    int j;
    for (j = 0; j < reply->elements; j++) {
        groupnames[j] = strdup(reply->element[j]->str);
    }
    freeReplyObject(reply);

    for (j = 0; j < count; j++) {
        reply = redisCommand(ctx, "SMEMBERS %s", groupnames[j]);
        printf("Group %s\n\tMembers: ", groupnames[j]);
        int k;
        for (k = 0; k < reply->elements; k++) {
            printf("%s ",
                reply->element[k]->str);
        }
        printf("\n");
        freeReplyObject(reply);
    }

    for (j = 0; j < count; j++)
        free(groupnames[j]);
    free(groupnames);
}
```

Of course, we have to be able to add members to a group (checking that the group name is known before trying to store more data):

```
static void addMember() {
    char groupname[128];
    char membername[128];
    printf("Adding student to group\n");
    printf("Group      : ");
    getstr(groupname, 128);
    printf("Student id : ");
    getstr(membername, 128);
    redisReply *reply;
    reply = redisCommand(ctx, "SISMEMBER Groups %s", groupname);
    int res = (0 == reply->integer);
    freeReplyObject(reply);

    if (res) {
        printf("There was no group with that id\n");
    } else {
        reply = redisCommand(ctx, "SADD %s %s", groupname, membername);
        freeReplyObject(reply);
    }
}
```

May need to remove members:

```
static void removeMember() {
    char groupname[128];
    char membername[128];
    printf("Removing student from group\n");
    printf("Group      : ");
    getstr(groupname, 128);
    printf("Student id : ");
    getstr(membername, 128);
    redisReply *reply;
    reply = redisCommand(ctx, "SISMEMBER Groups %s", groupname);
    int res = (0 == reply->integer);
    freeReplyObject(reply);

    if (res) {
        printf("There was no group with that id\n");
    } else {
        reply = redisCommand(ctx, "SREM %s %s", groupname, membername);
        freeReplyObject(reply);
    }
}
```


Project commands

The project commands are handled through another menu-select loop:

```
static void handleProjectCommands() {
    for (;;) {
        printf("Project=>");
        char command[128];
        getstr(command, 128);
        if (command[0] == 'q') break;
        if (command[0] == '?') {
            printf("Project Commands:\n");
            printf("\t? : print this command list\n");
            printf("\tq : finish project commands\n");
            printf("\tAdd: Add a project\n");
            printf("\tDelete: Delete a project\n");
            printf("\tList: List projects\n");
        }
        if (0 == strcmp(command, "Add")) addProject();
        else
            if (0 == strcmp(command, "Delete")) deleteProject();
        else
            if (0 == strcmp(command, "List")) listProjects();
    }
}
```

When a project is added, the title and name of the supervisor must be entered.

Titles will typically have multiple words separated by spaces, so we want to read the entire line. The `gets()` function in C is a pain with its handling of newline characters etc; it is better to use `fgets` which provides more control. Here, a little auxiliary function is used to read strings with `fgets`, and to remove the newline character from any string that is read.

```
static void getstr(char* str, int maxlen) {
    memset(str, 0, maxlen);
    fgets(str, maxlen, stdin);
    // fgets includes the terminating newline character for a string
    // will usually want this removed
    int len = strlen(str);
    len--;
    if (str[len] == '\n') str[len] = '\0';
}
```

The code for addProject is:

```
static void addProject() {
    printf("Project title : ");
    char title[128];
    getstr(title, 128);

    printf("Supervisor   : ");
    char supervisor[128];
    getstr(supervisor, 128);

    redisReply *reply;
    reply = redisCommand(ctx, "INCR projectcount");
    int account = (int) reply->integer; // It is a long long, but we won't have that many projects
    freeReplyObject(reply);

    char projid[128];
    memset(projid, 0, 128);
    sprintf(projid, "Project:%d", account);

    // Add the project id to the set of all projects
    reply = redisCommand(ctx, "SADD Projects %s", projid);
    freeReplyObject(reply);
    // Create a hash named by project id with values for title and supervisor
    reply = redisCommand(ctx, "HMSET %s Title %s Supervisor %s",
        projid, title, supervisor);
    freeReplyObject(reply);
}
```

The Redis counter variable projectcount is incremented and used when creating a project id. This id is added to the set of project identifiers maintained in Redis. A simple hash table structure is then created as the value of the project record in Redis.

Projects may get deleted:

```
static void deleteProject() {
    char pname[128];

    printf("Delete project with id : ");
    getstr(pname, 128);

    redisReply *reply;
    reply = redisCommand(ctx, "SISMEMBER Projects %s", pname);
    int res = (0 == reply->integer);
    freeReplyObject(reply);

    if (res) {
        printf("There was no project with that id\n");
    } else {
        // Remove id from set
        reply = redisCommand(ctx, "SREM Projects %s", pname);
        // Not checking confirmation, just assume it works
        freeReplyObject(reply);
        // Now remove the project details
        reply = redisCommand(ctx, "DEL %s", pname);
        freeReplyObject(reply);
    }
}
```

They get listed:

```
static void ListProjects() {
    redisReply *reply;
    reply = redisCommand(ctx, "SCARD Projects");

    int count = (int) reply->integer;
    freeReplyObject(reply);
    printf("There are %d projects currently in the database\n",
        count);
    char** projnames = malloc(count * sizeof (char*));
    reply = redisCommand(ctx, "SMEMBERS Projects");
    int j;
    for (j = 0; j < reply->elements; j++) {
        projnames[j] = strdup(reply->element[j]->str);
    }
    freeReplyObject(reply);

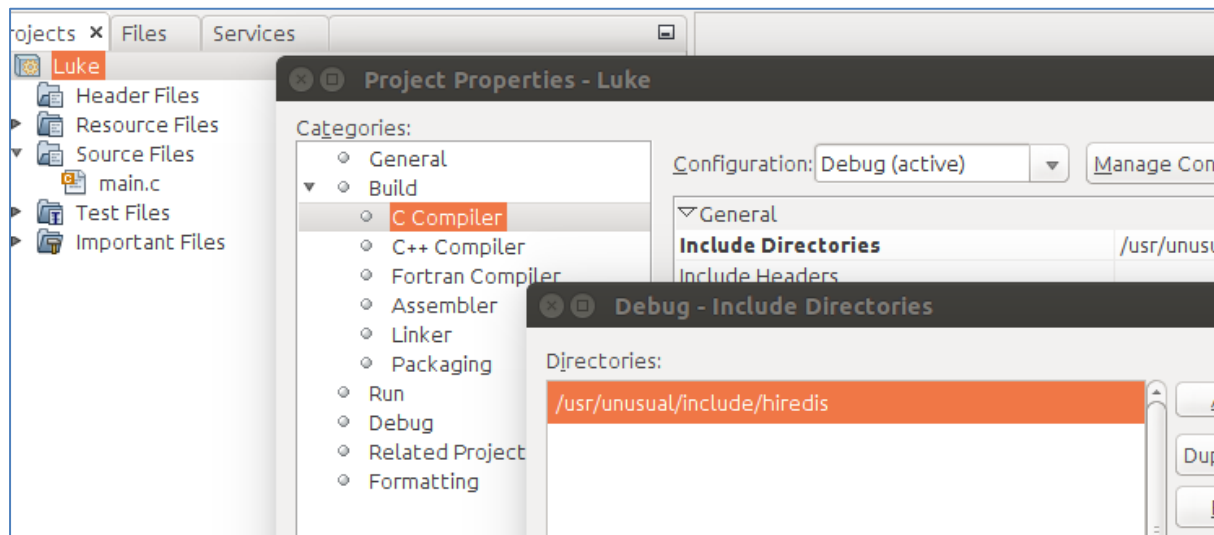
    for (j = 0; j < count; j++) {
        reply = redisCommand(ctx, "HGETALL %s", projnames[j]);
        printf("Project %s\n", projnames[j]);
        int k;
        for (k = 0; k < reply->elements; k += 2) {
            printf("%s: %s\n",
                reply->element[k]->str,
                reply->element[k + 1]->str);
        }
        freeReplyObject(reply);
    }

    for (j = 0; j < count; j++)
        free(projnames[j]);
    free(projnames);
}
```

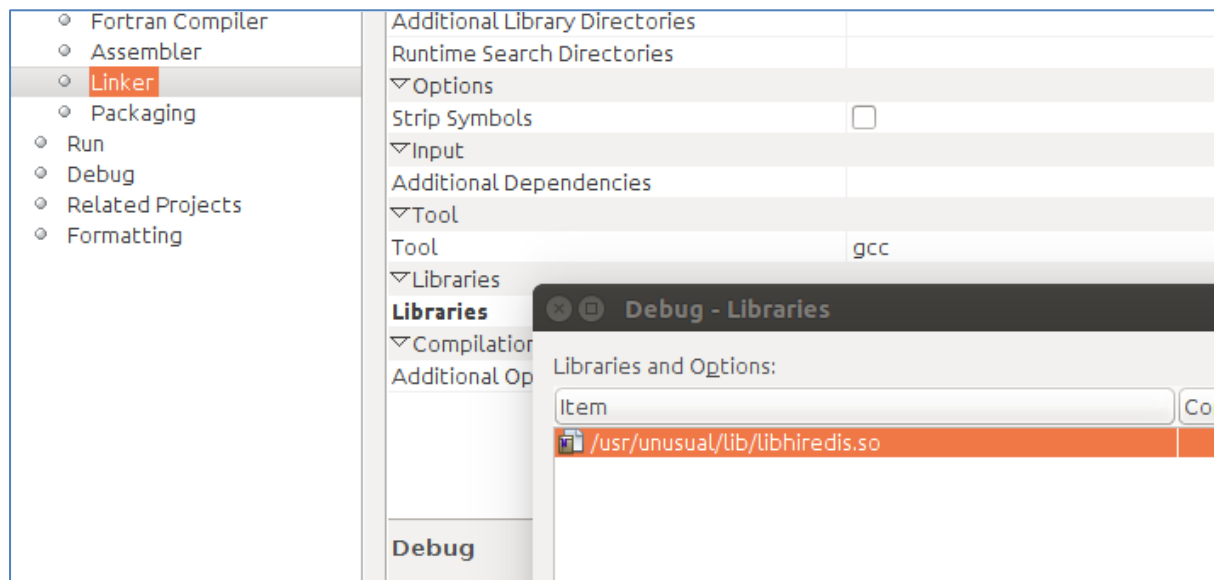
Building the project in NetBeans

The project properties will have to be edited in NetBeans. As 'hiredis' is a non-standard library in a non-standard location, the compiler and linker must both be given details of where to find header files and link files.

The compiler will need extra include directories:

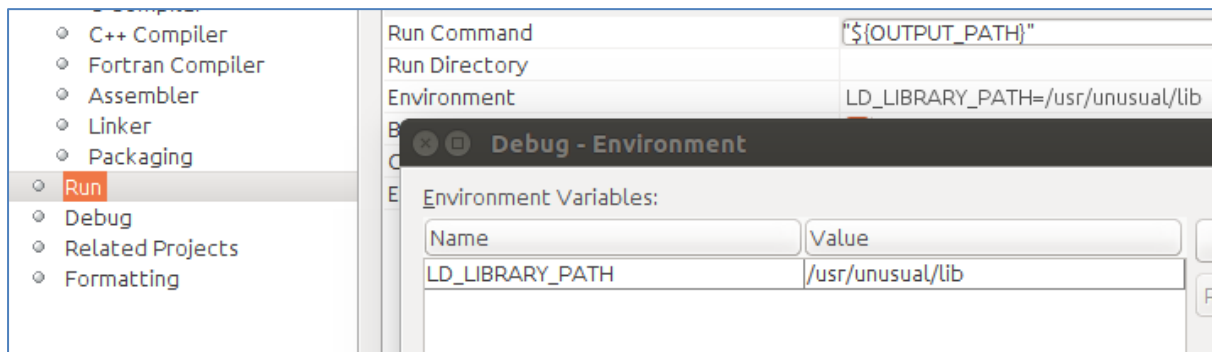


The linker needs the library. This build is using the .so shared object library; so the linking process is really just checking that functions are defined there in the library. A complete executable is not actually built:



If you simply tried to run the application as built, it would fail at run-time as it wouldn't find the libhiredis.so library.

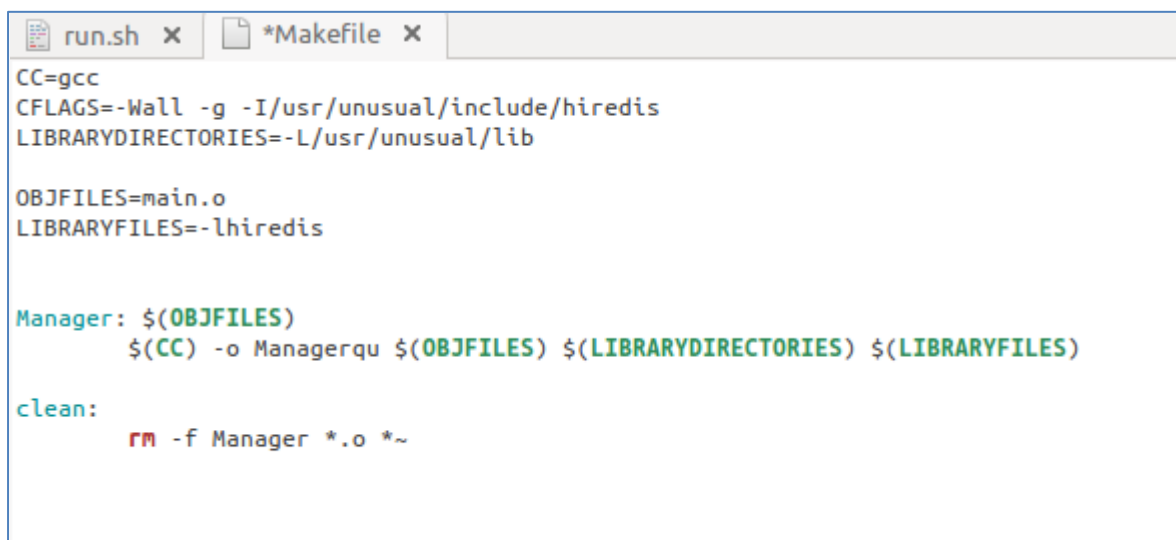
In a case like this, it is necessary to set the LD_LIBRARY_PATH so that at run-time the libhiredis.so library can again be found. In NetBeans this is achieved by setting a run-time environment variable.



You should be able to build and run the application from inside NetBeans.

Building the project without NetBeans

Once you have got the program to run correctly via NetBeans, you should create a stand-alone copy using your own makefile.

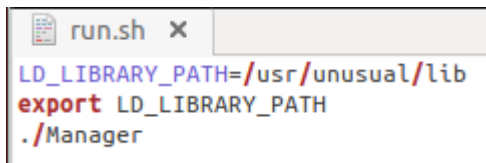


The value of CFLAGS now has a -I element – this is adding the location where the compiler can find the <hiredis.h> file that is included by the program. The LIBRARYFILES and LIBRARYDIRECTORIES elements identify the location and library name for use by the linker. This script builds the application as Manager.

If you attempt to run this application, it will fail at run-time. The dynamic linker will not find the libhiredis.so file. You must set the environment variable LD_LIBRARY_PATH, and 'export' the value once set. As noted in the lectures, this tends to be error prone.

One trick that is commonly used for programs that require unusual values for environment variables is to create a shell script that sets those values and then runs the program. The application is then always launched via this shell script.

For this example, the script would be:



```
run.sh x
LD_LIBRARY_PATH=/usr/unusual/lib
export LD_LIBRARY_PATH
./Manager
```

(Create the script, and assign appropriate execute permissions.) You should be able to get the application to run at the command line.

Exercises complete

Show the tutor that you have completed all the parts.

(That was 6 very easy marks wasn't it – just copy my code. Hopefully, you learnt a little more C, have become more aware of the libraries that are standard, and are more confident in your use of make and makefiles.)

Assignment

The [assignment](#): build an application exploiting several common, and less common, libraries.