CS601: Software Development for Scientific Computing

Autumn 2023

Week3: Programming Environment (contd), Makefile

C++ standard types

- Integer types: `char, short int, int, long int, long long int, bool`
- Float: `float, double, long double`
- `Pointers`: handle to addresses
- `References`: safer than pointers but less powerful
- `void`: nothing

C++ standard types

- Compound types
  - pointers, structs, enums, arrays, etc.
- Modifiers
  - `short, long, signed, unsigned.`

types / representation

`E.g. int x;`

1. What is the set of values this variable can take on in C?

   -2^{31} to (2^{31} – *1*)

2. How should operations on this variable be handled? integer division is different from floating point divisions

   ```
   3 / 2 = 1  //integer division
   
   3.0 / 2.0 = 1.5  //floating-point division
   ```

3. How much space does this variable take up?

   32 bits

C++ standard types – storage space

Data type	Number of bytes
`char`	1
`short int`	2
`int / long int`	4
`long long int`	8
`float`	4
`double`	8
`long double`	12

- All built-in types are represented in memory as a contiguous set of bytes
- Use sizeof() operator to check the size of a type
  - e.g. `sizeof(int)`

Typedef

– Lets you give alternative names to C data types

– Example:

```
typedef unsigned char BYTE;
```

This gives the name `BYTE` to an `unsigned char` type. Now,

```
BYTE a;
BYTE b;
```

Are valid statements.

Typedef Syntax

```
typedef <existing_type> <new_type>;
```

- Resembles a definition/declaration without initializer;

  E.g. `int x;`

- Mostly used with user-defined types

User-defined Types

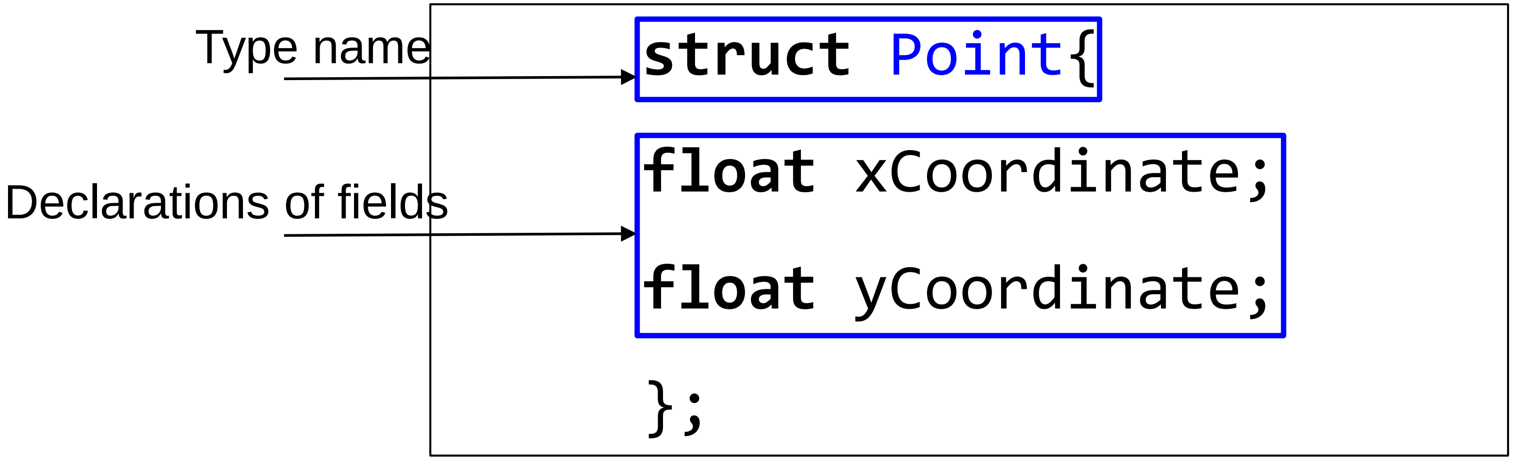
– *Structures* in C/C++ are one way of defining your own type.

– Arrays are compound types but have the *same* type within.

  - E.g. A string is an array of `char`
  - `int arr[]={1,2,3}; arr` is an array of integer types

– Structures let you compose types with *different* basic types within.

Structures - Declaration



Type name

Declarations of fields

```
struct Point{
float xCoordinate;
float yCoordinate;
};
```

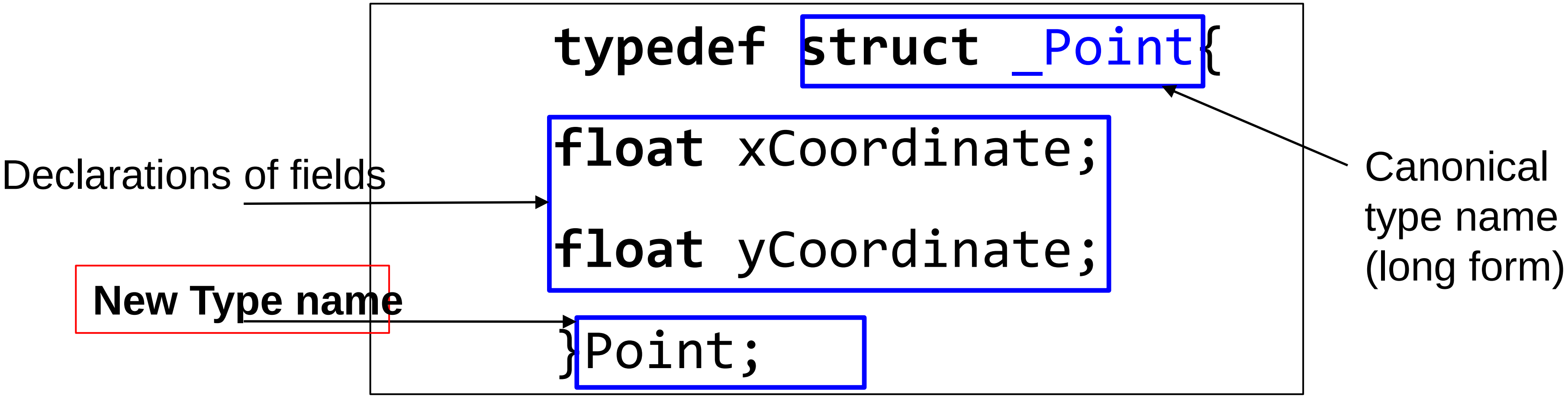
– Variable definition:

- `struct Point p1;`

-
  ```
  struct Point{
   float xCoordinate;
   float yCoordinate;
   }p1;
  ```

p1 is a variable (an object) of type `struct Point`

Structures - Definition



```
typedef struct _Point{
float xCoordinate;
float yCoordinate;
}Point;
```

Declarations of fields

New Type name

Canonical type name (long form)

- Variable definition:
  - `Point p1;`

Structures - Usage

- – Structure fields are accessed using dot (.) operator
- – Example:

```
Point p;

p.xCoordinate = 10.1;

p.yCoordinate = 22.8;

printf(“(x,y)=(%f,%f)\n”,p.xCoordinate,
p.yCoordinate);
```

Structures - Initialization

– Error to initialize fields in declaration;

```
typedef struct{
float xCoordinate = 10.1;
float yCoordinate = 22.8;
}Point;
```

Data types - quirks

- if no type is given compiler automatically converts it to `int` data type.
  - `signed x;`
- `long` is the only modifier allowed with `double`
  - `long double y;`
- `signed` is the default modifier for `char` and `int`
- Can’t use any modifiers with `float`

Exercise

```
char s[3] = “Hi”;

char *t = “Si”;

int u[3] = {5, 6, 7};

int n=8;
```

Expression	Type	Comments
`s`	`char[3]`	array of 3 chars
`t`	`char*`	address of a char
`u`	`int[3]`	array of 3 ints
`&u[0]`	`int*`	address of an int

Exercise

```
char s[3] = “Hi”;
char *t = “Si”;
int u[3] = {5, 6, 7};
int n=8;
```

Expression	Type	Comments
`*&n`	`int`	value at n
`*t`	`char`	data at address Held by t

Exercise

- Array initializers:

```
1. int u[3] = {5, 6};
```

Is this valid?

If yes, what is the value held in the third element u[2]?

```
2. int u[3] = {5, 6, 7, 8};
```

Is this valid?

```
3. char s1[]=“Hi”;
```

What is the size of s1? (how many bytes are reserved for s1)

```
4. char s2[3]=“Si”;
```

Is this valid?

Exercise

```
int u[3] = {5, 6, 7};
int* p=u;
p[0]=7;
p[1]=6;
p[2]=5;
```

//Now, u would contain the numbers in reverse order.

```
u[0] = 7, u[1]=6, u[2]=5.
```

```
char *str = “Hello”;
char* p=str;
p[0]=‘Y’;
```

//Now, what would `str` contain?

Program layout in memory

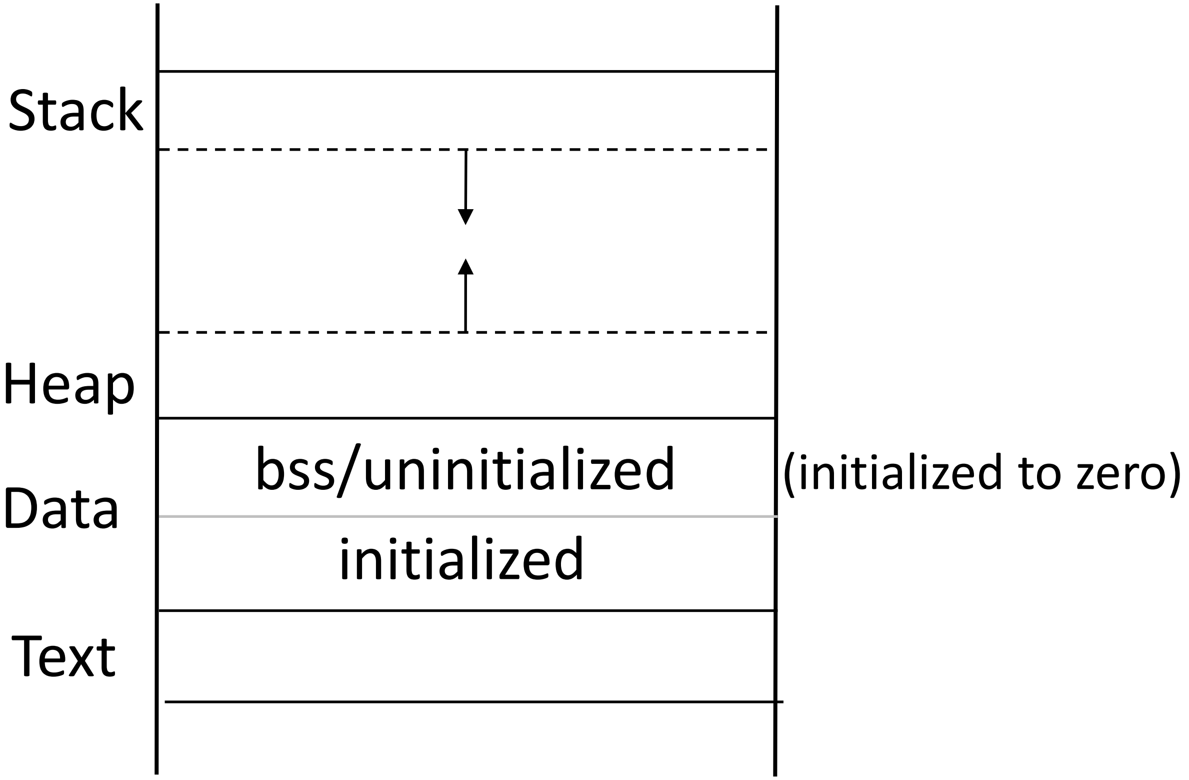
- How is a program laid out in memory?
  - Helpful to debug
  - Helpful to create robust software
  - Helpful to customize program for embedded systems

Program Layout in Memory

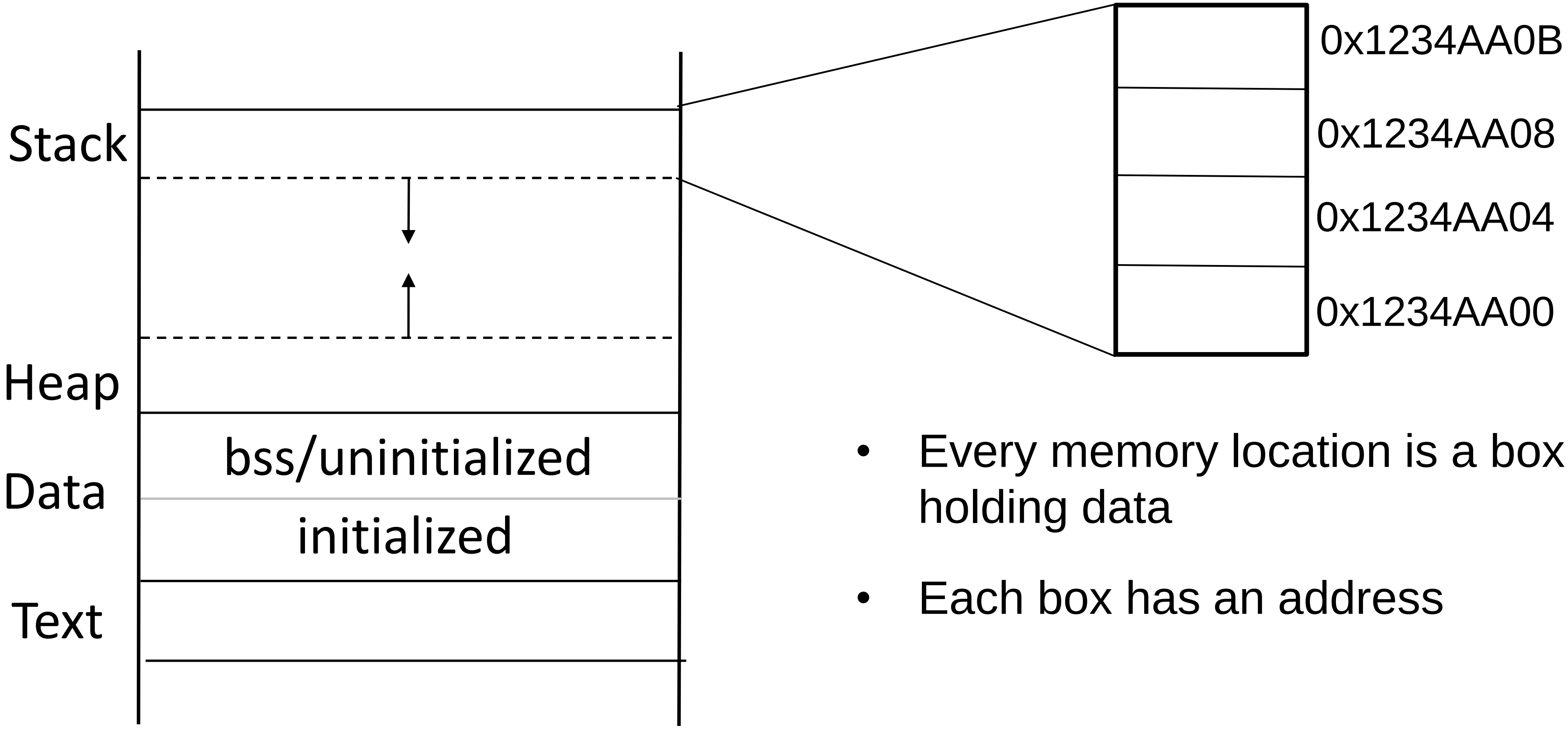
- A program’s memory space is divided into four segments:

1. Text
   - source code of the program
2. Data
   - Broken into uninitialized and initialized segments; contains space for global and static variables. E.g. `int x = 7; int y;`
3. Heap
   - Memory allocated using malloc/calloc/realloc/new
4. Stack
   - Function arguments, return values, local variables, special registers.

Program Layout in Memory

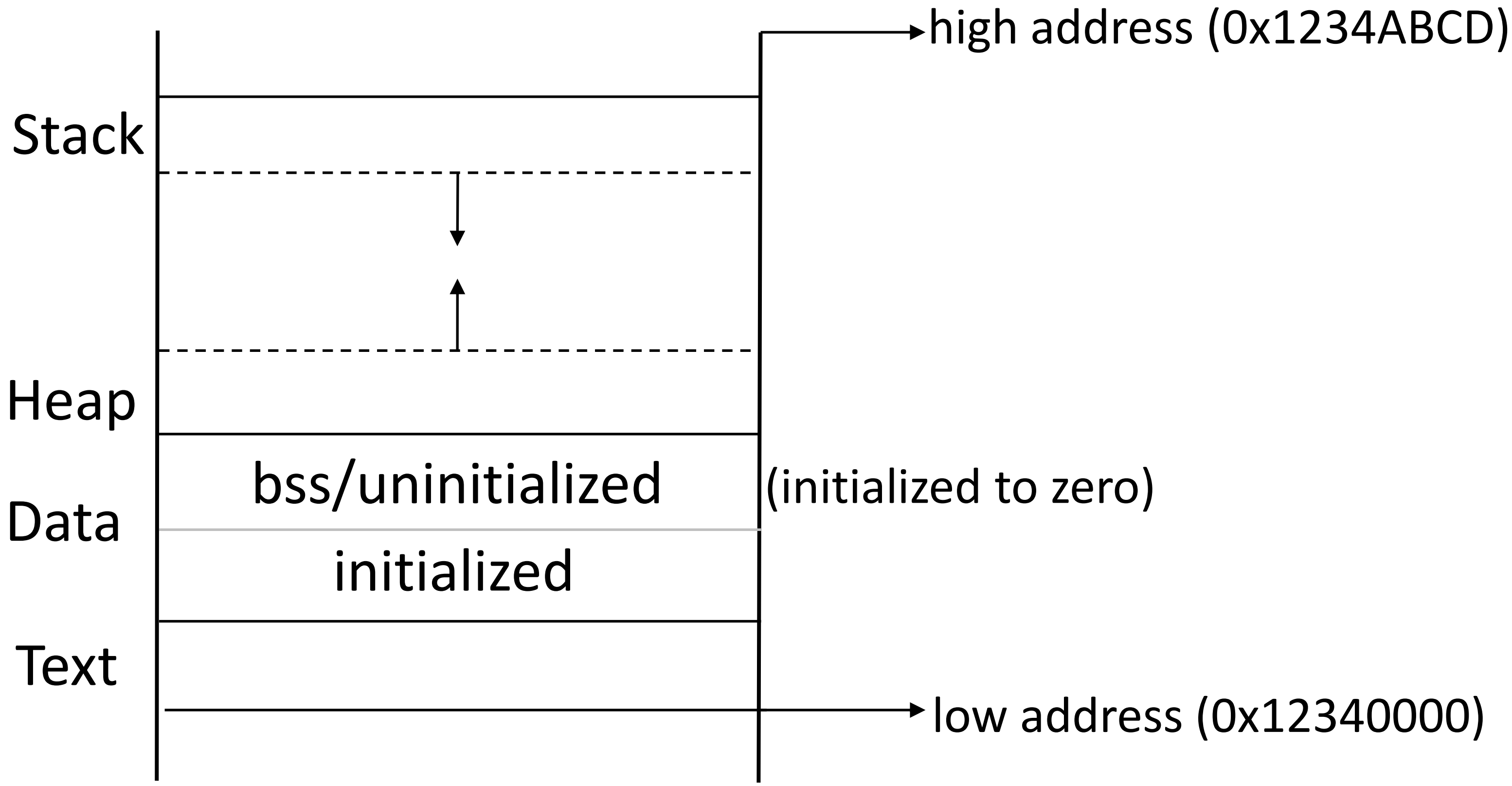


Program Layout in Memory



- Every memory location is a box holding data
- Each box has an address

Program Layout in Memory



Exercise

- Write a C++ program with the following requirements:
  - User should be able to provide the dimension of two vectors (*do not use C++ vectors from STL*)
  - The program should allocate two vectors of the required size and initialize them with meaningful data
  - The program should compute the scalar product of the two vectors and print the result

Discussion

Refer to:

- `vectorprod_v1.cpp`
  - What if `atoi` doesn't provide accurate status about the value returned?
- `vectorprod_v2.cpp`
  - `C++ stringstreams are an option. Is this code modular?`
- `vectorprod_v3.cpp scprod.cpp`
  - `What if there is already built-in function by the same name?`
- `vectorprod_v4.cpp scprod_v4.cpp`
  - `Namespaces`

`Makefile` or `makefile`

- Is a file, contains instructions for the `make` program to generate a *target* (executable).
- Generating a target involves:
  1. Preprocessing (e.g. strips comments, conditional compilation etc.)
  2. Compiling (.c -> .s files, .s -> .o files)
  3. Linking (e.g. making printf available)
- A `Makefile` typically contains directives/instructions on how to do steps 1, 2, and 3.

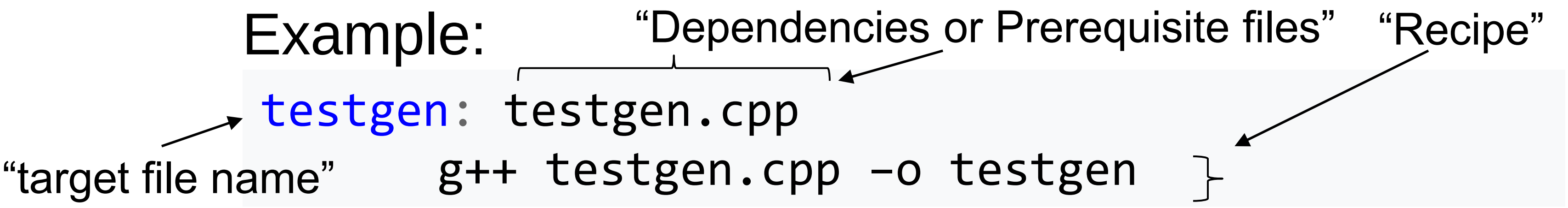
Makefile - Format

1. Contains series of ‘rules’-

```
target: dependencies
[TAB]  system command(s)
```

Note that it is important that there be a TAB character before the system command (not spaces).

Example:



“Dependencies or Prerequisite files”

“Recipe”

“target file name”

```
testgen: testgen.cpp
    g++ testgen.cpp –o testgen
```

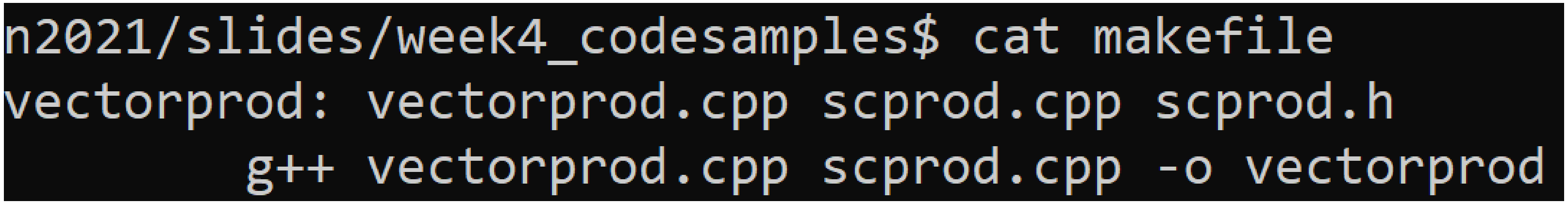
2. And Macro/Variable definitions -

```
CFLAGS = -std=c++11 -g -Wall -Wshadow --pedantic -Wvla –Werror

GCC  = g++
```

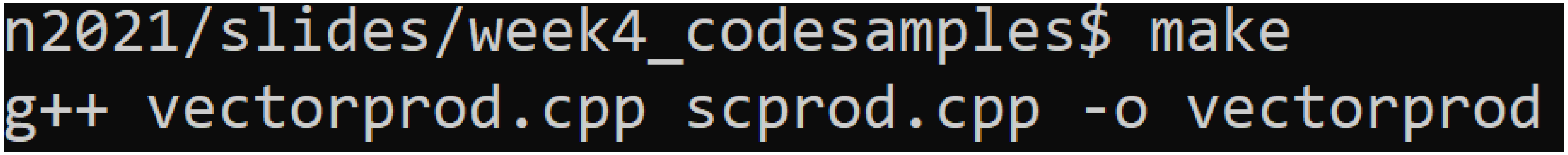
Makefile - Usage

– The ‘make’ command (Assumes that a file by name ‘makefile’ or ‘Makefile’. exists)



```
n2021/slides/week4_codesamples$ cat makefile
vectorprod: vectorprod.cpp scprod.cpp scprod.h
        g++ vectorprod.cpp scprod.cpp -o vectorprod
```

- Run the ‘make’ command



```
n2021/slides/week4_codesamples$ make
g++ vectorprod.cpp scprod.cpp -o vectorprod
```

`Makefile` - Benefits

- Systematic dependency tracking and building for projects
  - Minimal rebuilding of project
  - Rule adding is ‘declarative’ in nature (i.e. more intuitive to read *caveat: make also lets you write equivalent rules that are very concise and non-intuitive.*)
- To know more, please read: https://www.gnu.org/software/make/manual/html_node/index.html#Top