



Module 10

Instructors: Abir
Das and
Sourangshu
Bhattacharya

Objectives &
Outline

Memory
Management in C
`malloc` & `free`

Memory
Management in
C++

`new` & `delete`

Array

Placement `new`

Restrictions

Overloading `new`
& `delete`

Module Summary

Module 10: Programming in C++

Dynamic Memory Management

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Slides taken from NPTEL course on Programming in Modern C++

by **Prof. Partha Pratim Das**



Module Objectives

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Module Summary

- Understand the dynamic memory management in C++



Module Outline

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Module Summary

- 1 Dynamic Memory Management in C
 - malloc & free
- 2 Dynamic Memory Management in C++
 - new and delete operator
 - Dynamic memory allocation for Array
 - Placement new
 - Restrictions
- 3 Operator Overloading for Allocation and De-allocation
- 4 Module Summary



Program 10.01/02: malloc() & free(): C & C++

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C Program

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

int main() {
    int *p = (int *)malloc(sizeof(int));
    *p = 5;

    printf("%d", *p); // Prints: 5

    free(p);
}
```

C++ Program

```
#include <iostream>
#include <cstdlib>
using namespace std;

int main() {
    int *p = (int *)malloc(sizeof(int));
    *p = 5;

    cout << *p; // Prints: 5

    free(p);
}
```

- Dynamic memory management functions in `stdlib.h` header for C (`cstdlib` header for C++)
- `malloc()` allocates the memory on heap or free store
- `sizeof(int)` needs to be provided
- Pointer to allocated memory returned as `void*` – needs cast to `int*`
- Allocated memory is released by `free()` from heap or free store
- `calloc()` and `realloc()` also available in both languages



Program 10.02/03: operator new & delete: Dynamic memory management in C++

- C++ introduces operators **new** and **delete** to dynamically allocate and de-allocate memory:

Functions `malloc()` & `free()`

```
#include <iostream>
#include <cstdlib>
using namespace std;

int main() {
    int *p = (int *)malloc(sizeof(int));
    *p = 5;
    cout << *p; // Prints: 5

    free(p);
}
```

- Function `malloc()` for allocation on heap
- `sizeof(int)` needs to be provided
- Allocated memory returned as `void*`
- *Casting to `int*` needed*
- *Cannot be initialized*
- Function `free()` for de-allocation from heap
- Library feature – header `cstdlib` needed

operator new & operator delete

```
#include <iostream>
using namespace std;

int main() {
    int *p = new int(5);

    cout << *p; // Prints: 5

    delete p;
}
```

- **operator new** for allocation on heap
- *No size* specification needed, *type suffices*
- Allocated memory returned as `int*`
- *No casting needed*
- *Can be initialized*
- **operator delete** for de-allocation from heap
- Core language feature – no header needed



Program 10.02/04: Functions: operator new() & operator delete()

- C++ also allows `operator new()` and `operator delete()` functions to dynamically allocate and de-allocate memory:

Functions `malloc()` & `free()`

```
#include <iostream>
#include <cstdlib>
using namespace std;

int main() {
    int *p = (int *)malloc(sizeof(int));
    *p = 5;

    cout << *p; // Prints: 5

    free(p);
}
```

- Function `malloc()` for allocation on heap
- Function `free()` for de-allocation from heap

Functions `operator new()` & `operator delete()`

```
#include <iostream>
#include <cstdlib>
using namespace std;

int main() {
    int *p = (int *)operator new(sizeof(int));
    *p = 5;

    cout << *p; // Prints: 5

    operator delete(p);
}
```

- Function `operator new()` for allocation on heap
- Function `operator delete()` for de-allocation from heap

There is a major difference between `operator new` and function `operator new()`. We explore this angle later



Program 10.05/06: new[] & delete[]: Dynamically managed Arrays in C++

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Functions malloc() & free()

```
#include <iostream>
#include <cstdlib>
using namespace std;

int main() {
    int *a = (int *)malloc(sizeof(int)* 3);
    a[0] = 10; a[1] = 20; a[2] = 30;

    for (int i = 0; i < 3; ++i)
        cout << "a[" << i << "] = "
            << a[i] << "    ";

    free(a);
}
-----
a[0] = 10    a[1] = 20    a[2] = 30
```

- Allocation by `malloc()` on heap
- # of elements implicit in size passed to `malloc()`
- Release by `free()` from heap

operator new[] & operator delete[]

```
#include <iostream>
using namespace std;

int main() {
    int *a = new int[3];
    a[0] = 10; a[1] = 20; a[2] = 30;

    for (int i = 0; i < 3; ++i)
        cout << "a[" << i << "] = "
            << a[i] << "    ";

    delete [] a;
}
-----
a[0] = 10    a[1] = 20    a[2] = 30
```

- Allocation by `operator new[]` (different from `operator new`) on heap
- # of elements explicitly passed to `operator new[]`
- Release by `operator delete[]` (different from `operator delete`) from heap



Program 10.07: Operator new(): Placement new in C++

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```
#include <iostream>
using namespace std;
int main() { unsigned char buf[sizeof(int)* 2]; // Byte buffer on stack
            // placement new in buffer buf
            int *pInt = new (buf) int (3);
            int *qInt = new (buf+sizeof(int)) int (5);

            int *pBuf = (int *) (buf + 0);           // *pInt in buf[0] to buf[sizeof(int)-1]
            int *qBuf = (int *) (buf + sizeof(int)); // *qInt in buf[sizeof(int)] to buf[2*sizeof(int)-1]
            cout << "Buf Addr  Int Addr" << pBuf << " " << pInt << endl << qBuf << " " << qInt << endl;
            cout << "1st Int  2nd Int" << endl << *pBuf << "          " << *qBuf << endl;

            int *rInt = new int(7); // heap allocation
            cout << "Heap Addr  3rd Int" << endl << rInt << "          " << *rInt << endl;
            delete rInt;           // delete integer from heap
            // No delete for placement new
        }
}
-----
```

```
Buf Addr  Int Addr
001BFC50  001BFC50
001BFC54  001BFC54
1st Int   2nd Int
3         5
Heap Addr  3rd Int
003799B8   7
```

- Placement operator new takes a buffer address to place objects
- These are not dynamically allocated on heap – may be allocated on stack or heap or static, wherever the buffer is located
- Allocations by Placement operator new must not be deleted



Mixing Allocators and De-allocators of C and C++

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- Allocation and De-allocation must correctly match.
 - Do not free the space created by new using free()
 - And do not use delete if memory is allocated through malloc()

These may result in memory corruption

Allocator	De-allocator
malloc()	free()
operator new	operator delete
operator new[]	operator delete[]
operator new()	No delete

- Passing NULL pointer to delete operator is secure
- Prefer to use only new and delete in a C++ program
- The new operator allocates exact amount of memory from Heap or Free Store
- new returns the given pointer type – no need to typecast
- new, new[] and delete, delete[] have separate semantics



Program 10.08: Overloading operator new and operator delete

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```
#include <iostream>
#include <stdlib.h>
using namespace std;

void* operator new(size_t n) { // Definition of Operator new
    cout << "Overloaded new" << endl;
    void *ptr = malloc(n);    // Memory allocated to ptr. Can be done by function operator new()
    return ptr;
}

void operator delete(void *p) { // Definition of operator delete
    cout << "Overloaded delete" << endl;
    free(p);                  // Allocated memory released. Can be done by function operator delete()
}

int main() { int *p = new int; // Calling overloaded operator new
    *p = 30;                  // Assign value to the location
    cout << "The value is : " << *p << endl;
    delete p;                 // Calling overloaded operator delete
}
```

```
-----
Overloaded new
The value is : 30
Overloaded delete
```

- operator new overloaded
- The first parameter of overloaded operator new must be size_t
- The return type of overloaded operator new must be void*
- The first parameter of overloaded operator delete must be void*
- The return type of overloaded operator delete must be void
- More parameters may be used for overloading
- operator delete should not be overloaded (usually) with extra parameters



Program 10.09: Overloading operator new[] and operator delete[]

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```
#include <iostream>
#include <cstdlib>
using namespace std;

void* operator new [] (size_t os, char setv) { // Fill the allocated array with setv
    void *t = operator new(os);
    memset(t, setv, os);
    return t;
}

void operator delete[] (void *ss) {
    operator delete(ss);
}

int main() {
    char *t = new('#')char[10]; // Allocate array of 10 elements and fill with '#'

    cout << "p = " << (unsigned int) (t) << endl;
    for (int k = 0; k < 10; ++k)
        cout << t[k];

    delete [] t;
}

-----
p = 19421992
#####
```

- operator new[] overloaded with initialization
- The first parameter of overloaded operator new[] must be size_t
- The return type of overloaded operator new[] must be void*
- Multiple parameters may be used for overloading
- operator delete [] should not be overloaded (usually) with extra parameters



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Module Summary

- Introduced `new` and `delete` for dynamic memory management in C++
- Understood the difference between `new`, `new[]` and `delete`, `delete[]`
- Compared memory management in C with C++
- Explored the overloading of `new`, `new[]` and `delete`, `delete[]` operators