

Garbage Collection

- normally in C++ the default mechanism for managing dynamic memory is to use `new` and `delete`
- which are very similar to `malloc` and `free` found in C
- we note that in C++ we also need to provide copy and assignment operators
 - these also must copy dynamic data, often invoking `new` and `delete`

Garbage Collection

- there is a problem in handling the dynamic data, in particular returning dynamic data which is no longer required back to the free pool
- C++ manages this by its rule of three discussed in earlier lectures
- this works well
 - every time an object goes out of scope it is deleted
- however it can be costly, sometimes in time critical applications it might be better to delay the deallocation until later
 - consider real-time games
 - should be possible to create a thread to run the deallocation in parallel with the event loop

Example code

```
sfract v;  
sfract s;  
sfract radians;  
int i;  
sfract two_pi = 2 * pi ();  
  
two_pi.root ();  
  
for (i = 0; i<360; i += 15)  
{  
    s = sfract (i, 360);  
    radians = s * two_pi;  
    v = sin (radians);  
    std::cout << "sin (" << i << " degrees) can be expressed as " << v;  
    v = v();  
    std::cout << " and also " << v << "\n";  
    sfract_garbage_collect ();  
}
```

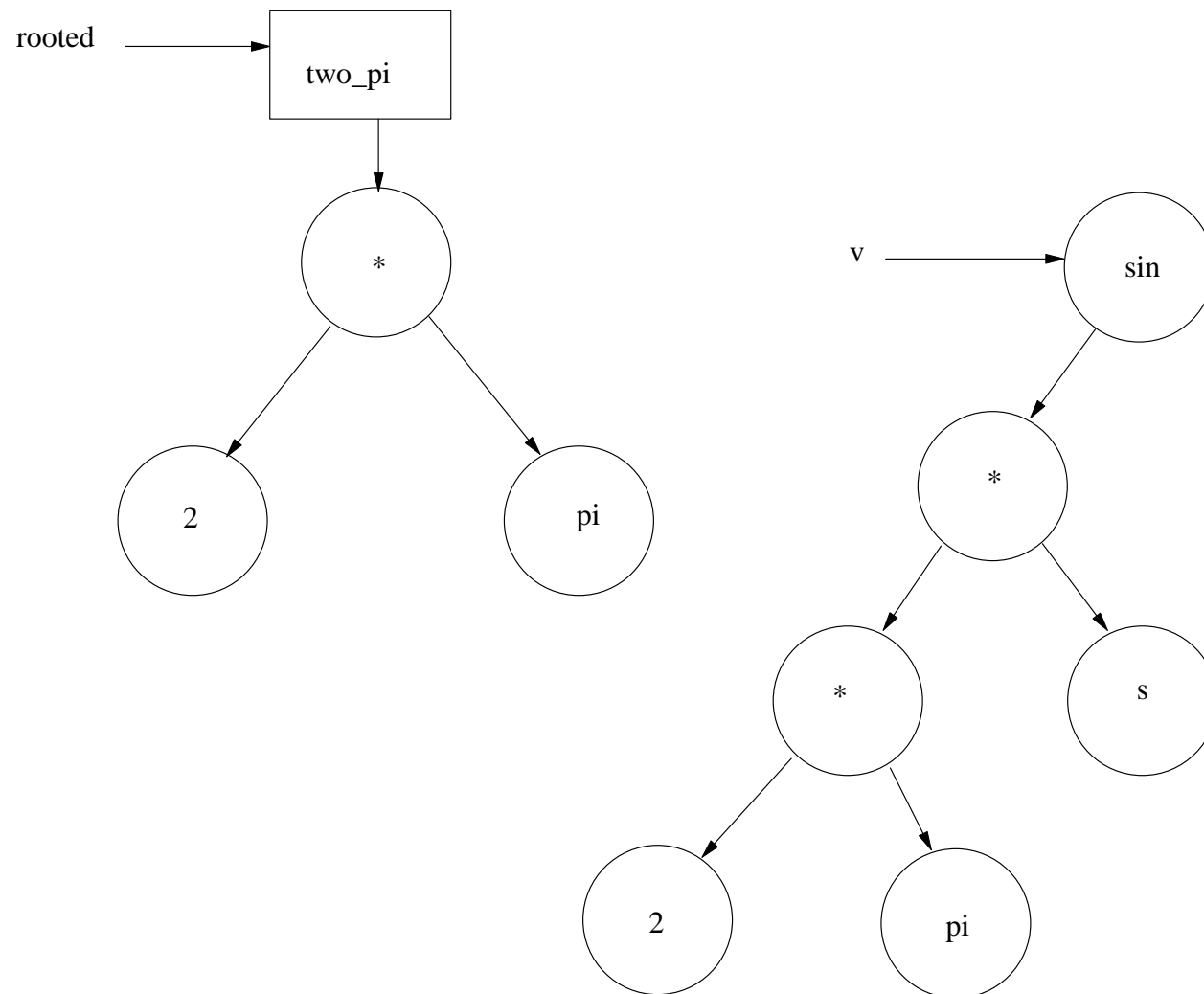
Garbage collection algorithm

- based on mark and sweep

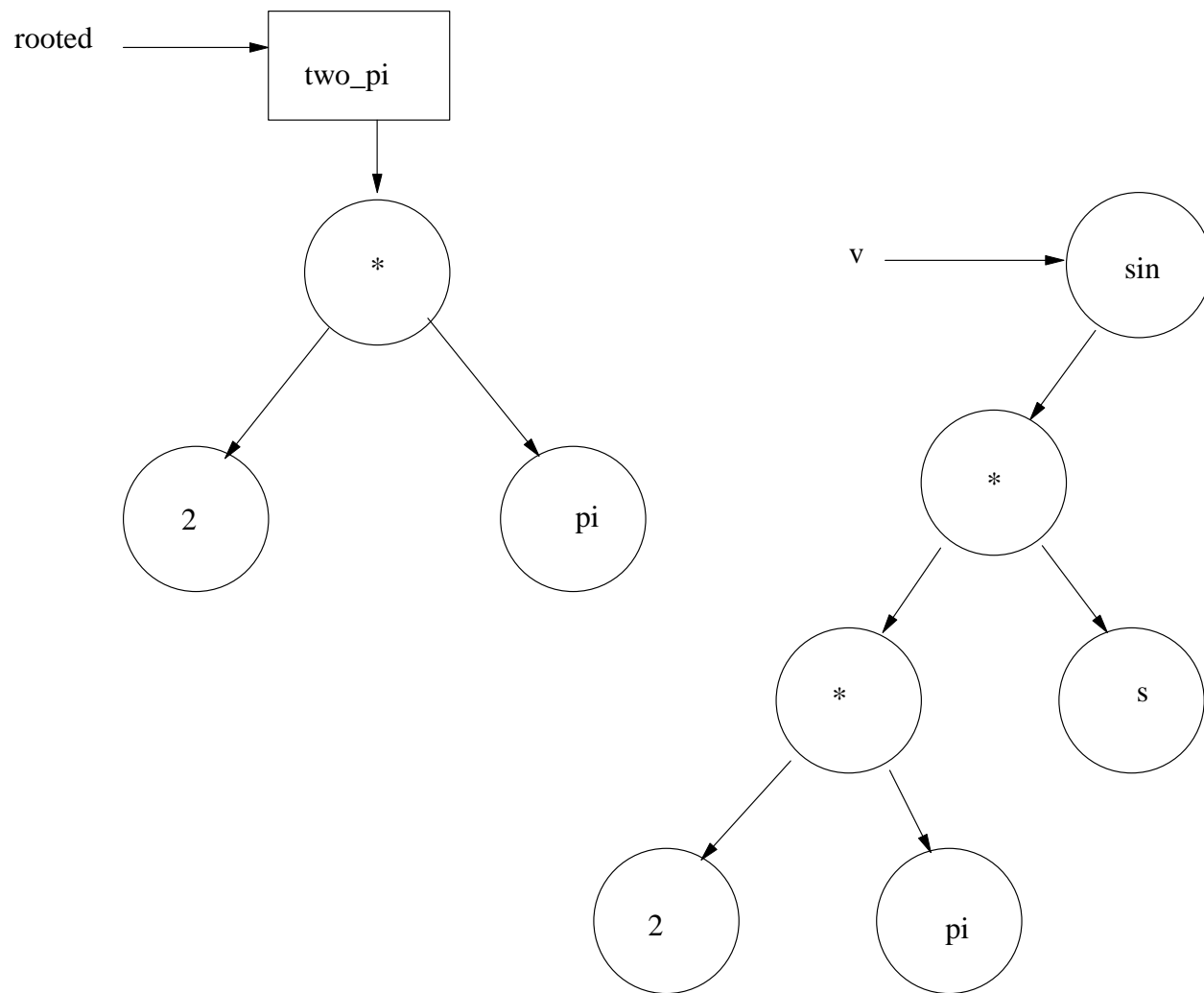
- the programmer `roots` critical data structures
 - indicating that these data structures must survive the garbage collection
 - also all rooted dependent data structures must survive the garbage collection

- in the above example the variable `two_pi` is rooted

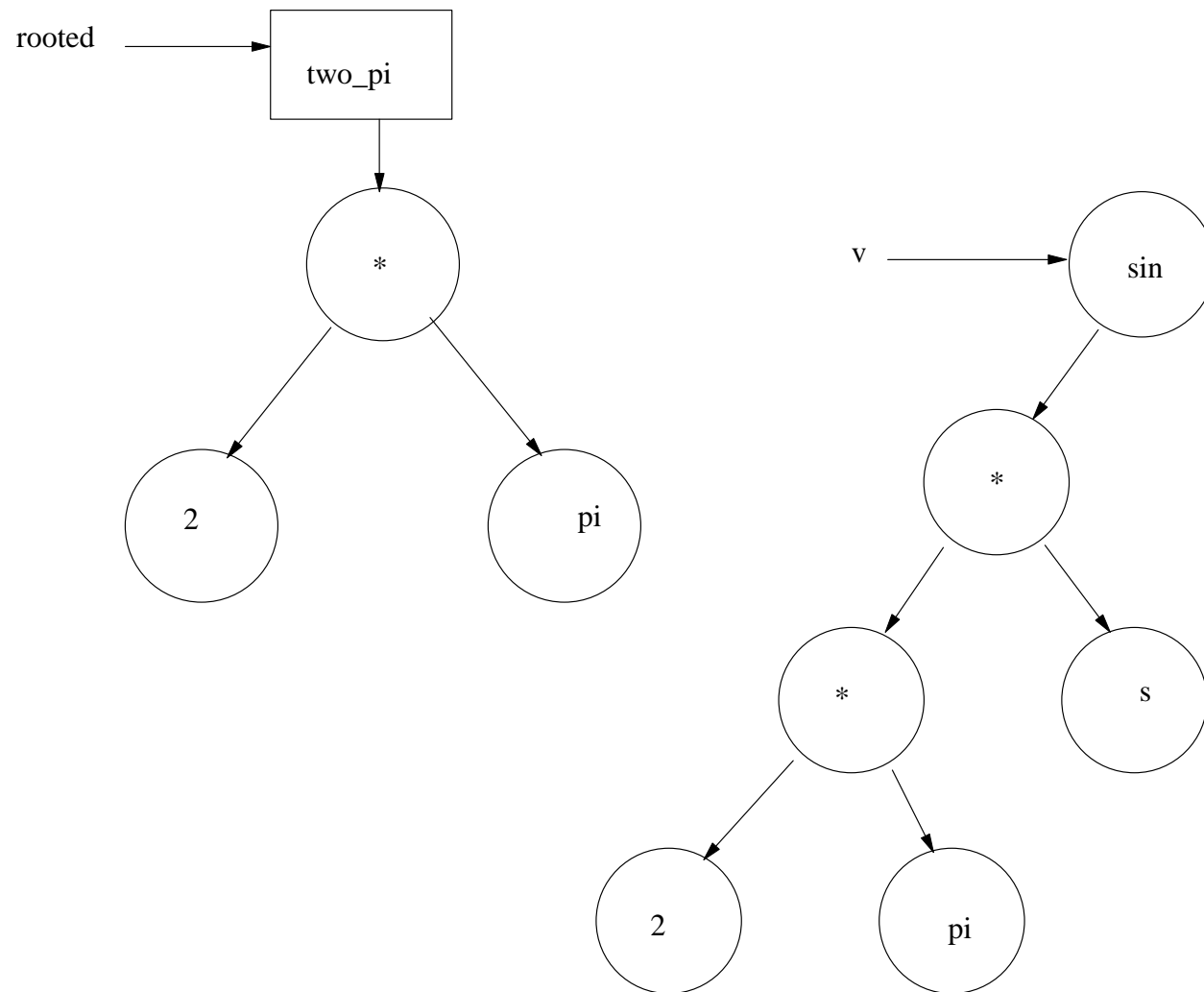
Action of Garbage collection



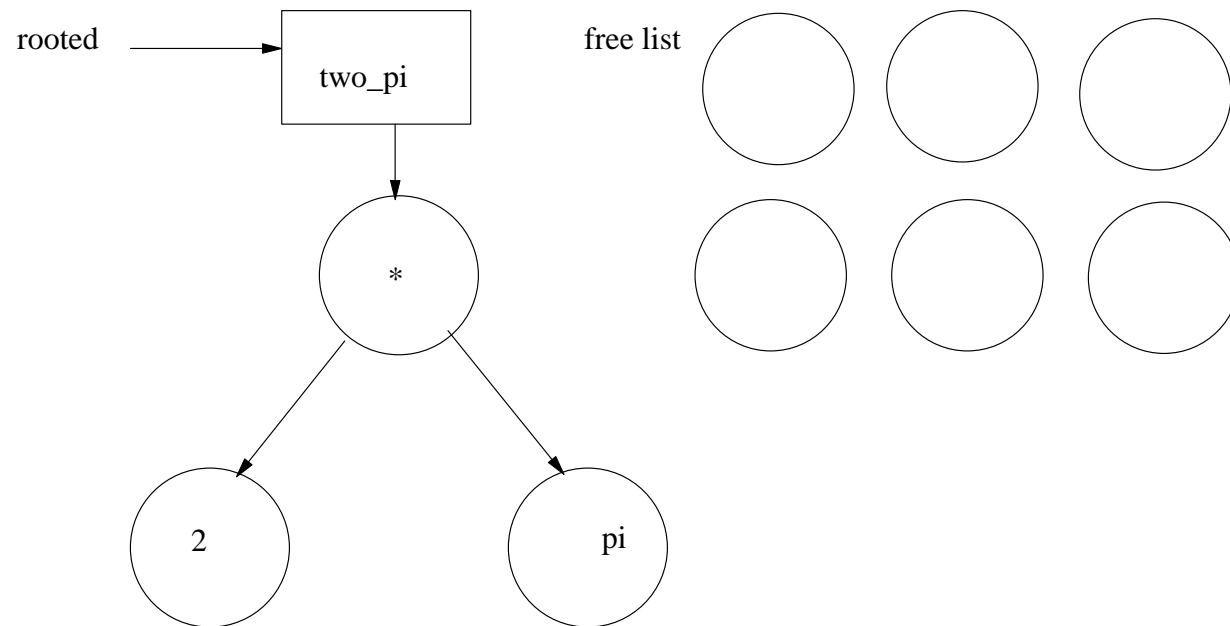
Mark all as candidates for removal



Set all root nodes and dependants used



Sweep any nodes still marked into free list



gc.h

examples/c++/fractions/gc.h

```
class gc
{
private:
    entity *rooted;
    entity *allocated;
    int     bytes;
    char    *desc;
    entity *free_list;
    gc      *next;
```

gc.h

examples/c++/fractions/gc.h

```
public:
    gc (int no_of_bytes, const char *description);
    ~gc ();
    void collect (void);
    void *allocate (entity *&e);
    void root (entity *e);
    void unroot (entity *e);
    void *get_data (entity *e);
    entity *get_entity (void *data);
    bool is_rooted (entity *e);
    void mark_allocated (void);

    void stats (void);
    int no_of_allocated (void);
    int no_of_freed (void);
    int no_of_rooted (void);
};
```

gc.h

examples/c++/fractions/gc.h

```
/*
 * garbage_collect - pre-condition : none.
 *                  post-condition: all the garbage collectors
 *                  will attempt to reclaim lost
 *                  memory.
 */

void garbage_collect (void);

/*
 * allocate - pre-condition:  init_garbage has been called to
 *                  maintain a, bytes, heap.
 *                  post-condition: entity, e, is filled in and the
 *                  allocated memory is returned.
 */

void *allocate (unsigned int bytes, entity *&e);
```

gc.h

examples/c++/fractions/gc.h

```
/*  
 *  init_garbage - pre-condition :  none.  
 *                post-condition:  a garbage collector is created  
 *                to serve calls for bytes amount  
 *                of memory.  
 */  
  
gc *init_garbage (unsigned int bytes, const char *description);  
  
#endif
```

gc.h

examples/c++/fractions/gc.h

```
typedef enum {freed = 1, marked = 2, in_use = 4,
             in_error=8, max_state = 16} state;

class entity
{
public:
    void    *data;
    state   status;
    entity  *a_next;
    entity  *r_next;
    entity  *f_next;

    entity (void);
    ~entity (void);
    entity (const entity &from); // copy
    entity& operator= (const entity &from); // assignment
};
```

gc.h

examples/c++/fractions/gc.h

```
void unmark (void);  
void mark (void);  
bool is_marked (void);  
  
void free (void);  
void unfree (void);  
bool is_free (void);  
  
void used (void);  
void unused (void);  
bool is_used (void);  
  
void do_assert (void);  
};
```



■ [examples/c++/fractions/gc.cc](#)

```
void *operator new (std::size_t bytes)
{
    entity *e;

    return allocate (bytes, e);
}
```



examples/c++/fractions/gc.cc

```
/*
 * allocate - pre-condition:  init_garbage has been called to
 *                          maintain a, bytes, heap.
 *                          post-condition: entity, e, is filled in and the
 *                          allocated memory is returned.
 */

void *allocate (unsigned int bytes, entity *&e)
{
    if ((bytes == sizeof (entity)) || (bytes == sizeof (gc)))
        return malloc (bytes);

    gc *g = list_of_gc->find_gc (bytes);

    if (g == 0)
        return malloc (bytes);    // no garbage collector initialised yet
    else
        return g->allocate (e);
}
```


Running your code before you have implemented garbage collection

■

```
sin (0 degrees) can be expressed as sin ((0 * (2 * pi))) and also 0
total number of entities 55

sin (15 degrees) can be expressed as sin ((1/24 * (2 * pi))) and ...
total number of entities 114

sin (30 degrees) can be expressed as sin ((1/12 * (2 * pi))) and ...
total number of entities 173

sin (45 degrees) can be expressed as sin ((1/8 * (2 * pi))) and ...
total number of entities 232
...

sin (315 degrees) can be expressed as sin ((7/8 * (2 * pi))) and ...
total number of entities 1294

sin (330 degrees) can be expressed as sin ((11/12 * (2 * pi))) and ...
total number of entities 1353

sin (345 degrees) can be expressed as sin ((23/24 * (2 * pi))) and ...
total number of entities 1412
```

Running your code once you have implemented garbage collection

■
sin (0 degrees) can be expressed as $\sin ((0 * (2 * \pi)))$ and also 0
total number of entities 109

sin (15 degrees) can be expressed as $\sin ((1/24 * (2 * \pi)))$ and ...
total number of entities 145

sin (30 degrees) can be expressed as $\sin ((1/12 * (2 * \pi)))$ and ...
total number of entities 145

sin (45 degrees) can be expressed as $\sin ((1/8 * (2 * \pi)))$ and ...
total number of entities 145

...

sin (315 degrees) can be expressed as $\sin ((7/8 * (2 * \pi)))$ and ...
total number of entities 145

sin (330 degrees) can be expressed as $\sin ((11/12 * (2 * \pi)))$ and ...
total number of entities 145

sin (345 degrees) can be expressed as $\sin ((23/24 * (2 * \pi)))$ and ...
total number of entities 145