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

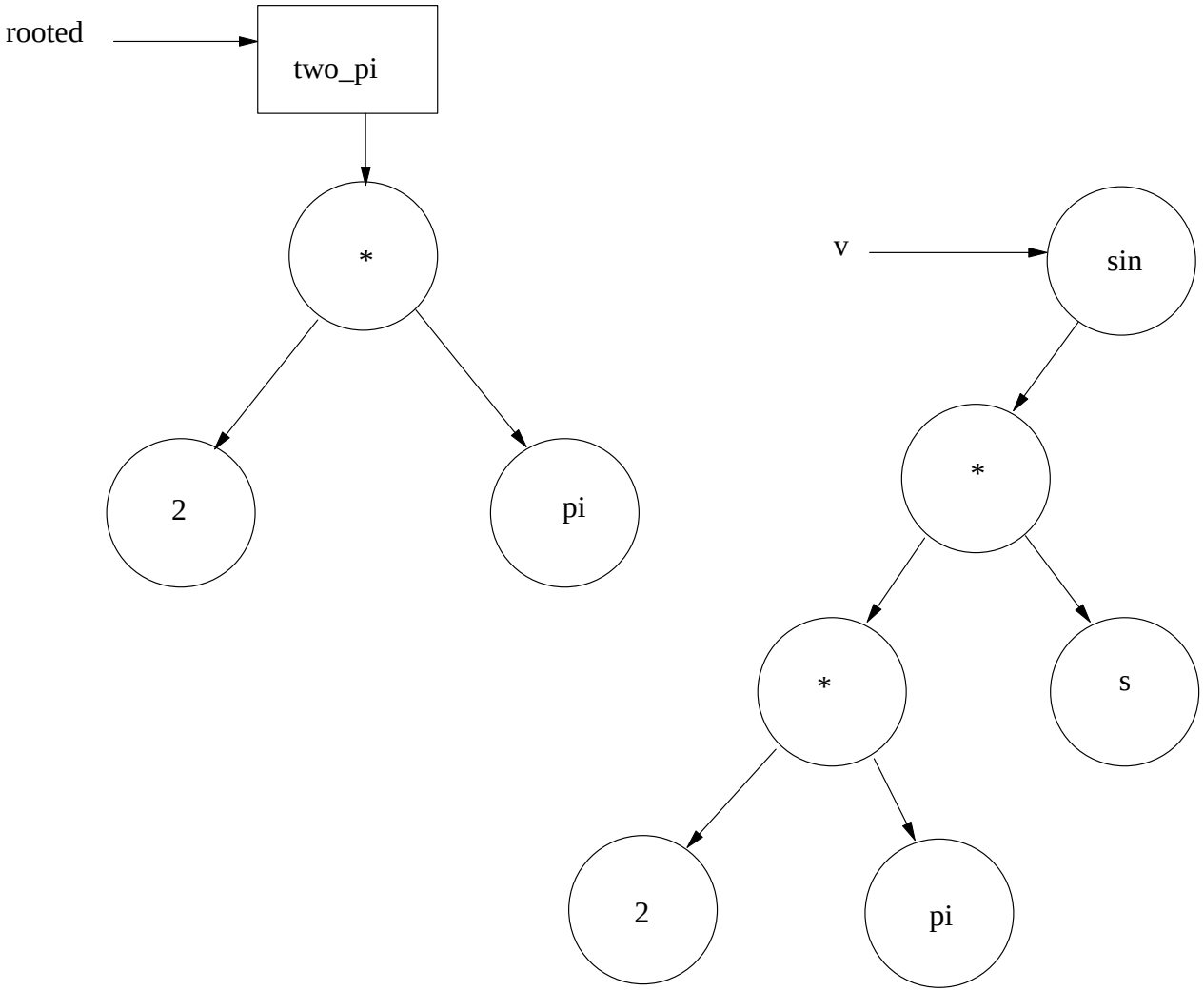
Example code

```
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 ();
  }
```

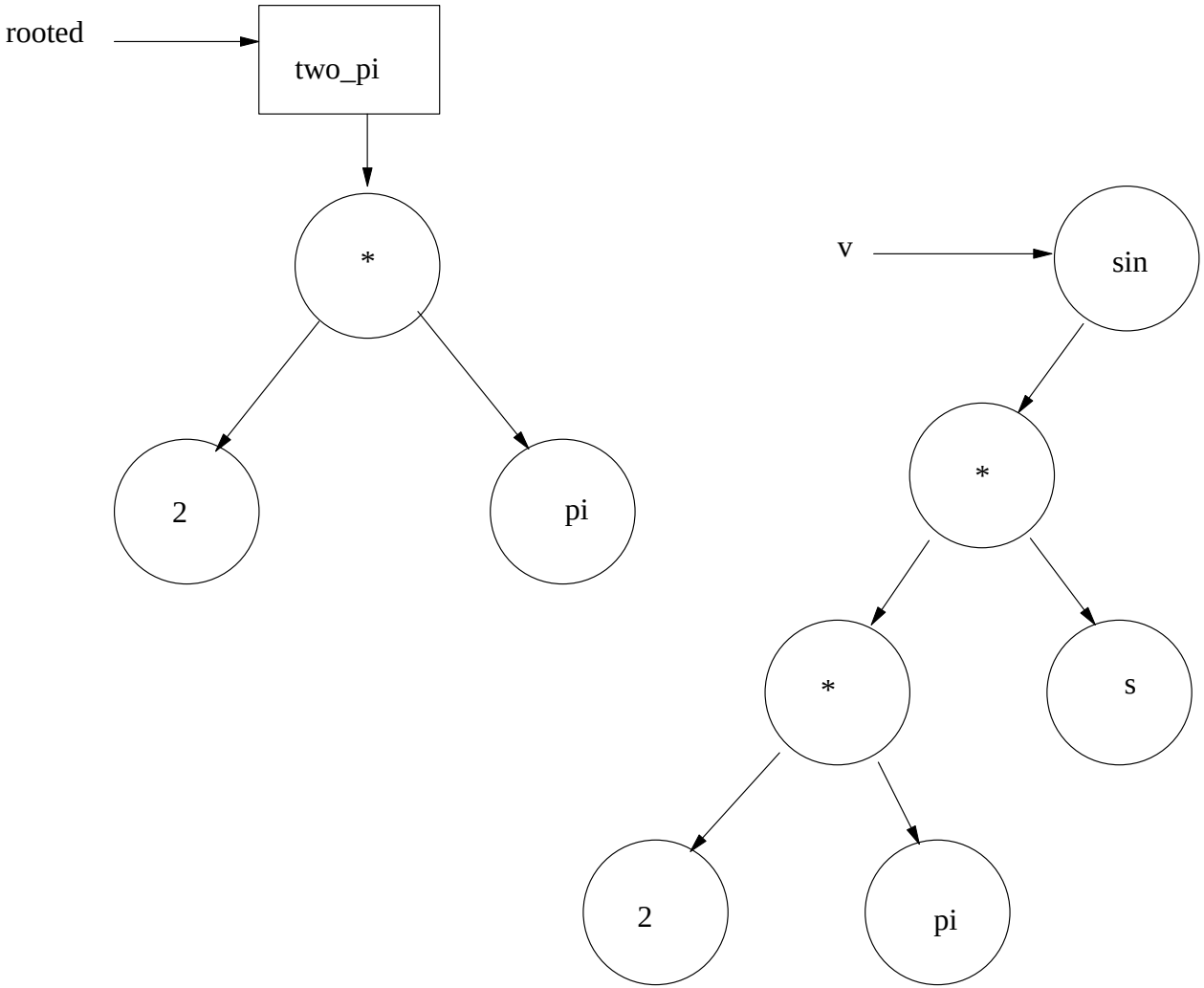
Garbage collection algorithm

- 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`

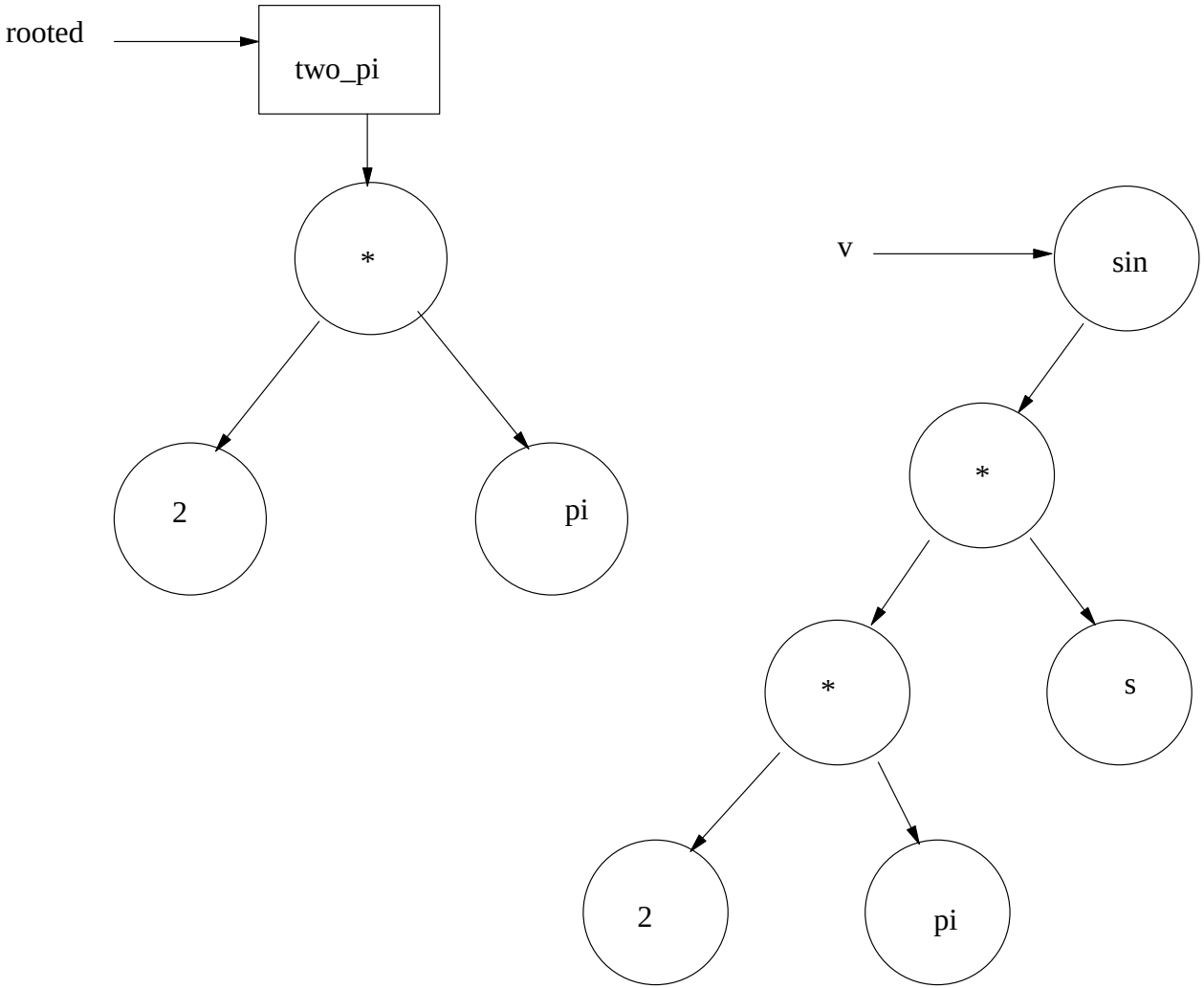
Action of Garbage collection



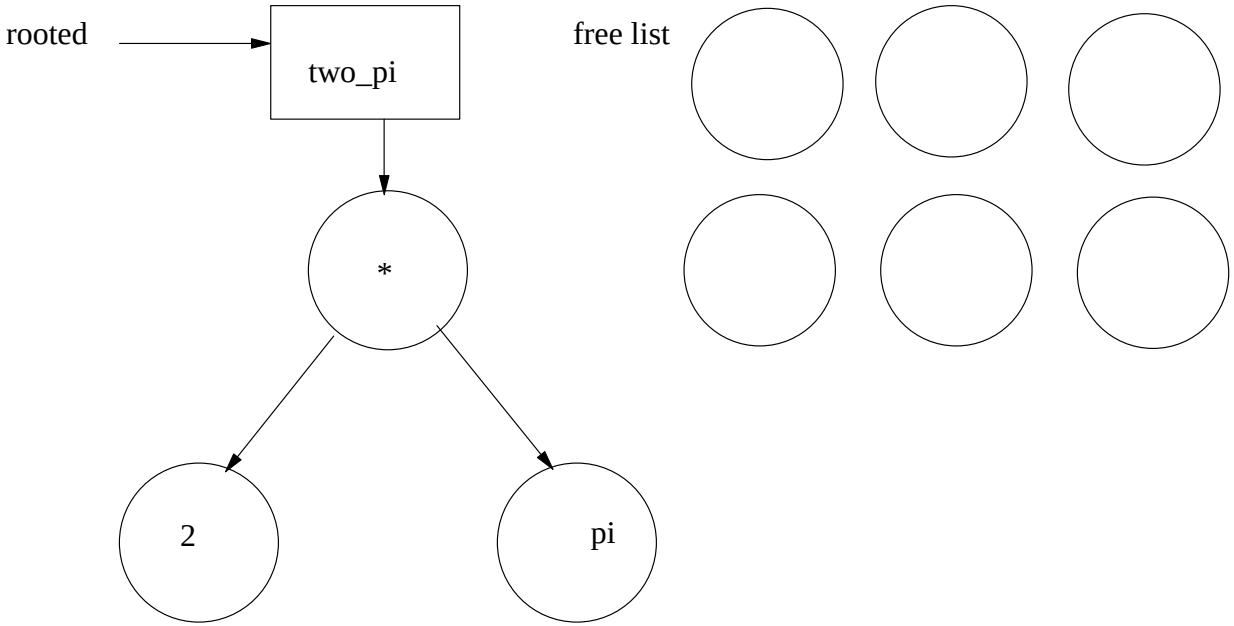
Mark all as candidates for removal



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);
};
```

gc.cc

examples/c++/fractions/gc.cc

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

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

gc.cc

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
```