Invariants and Encapsulation

EECS 211
Winter 2017
A struct encapsulating a binary search tree

struct Tree
{
    struct Node
    {
        std::string key;
        unsigned value;
        link_t left;
        link_t right;
    };
    using link_t = std::shared_ptr<Node>;
    link_t root_;          
    size_t size_;          
};
Invariants

Invariants are facts about a data structure that must always be true (for it to work properly).

- Operations must *preserve* invariants, and
- Consequently, operations can *rely* on invariants.
The **Tree** struct has invariants

For any **Tree** t,

- t.size\_ needs to equal the actual number of elements
- For every node n, all the keys of n.left must be less than n.key
- For every node n, all the keys of n.right must be greater than n.key
The **Tree** struct has invariants

For any **Tree** \( t \),

- \( t\).size\_ needs to equal the actual number of elements
- For every node \( n \), all the keys of \( n\).left must be less than \( n\).key
- For every node \( n \), all the keys of \( n\).right must be greater than \( n\).key

Then:

- Operations that need to know the size can safely use \( t\).size\_.
- Operations that modify need to maintain \( t\).size\_.
- Lookup operations can rely on ordering because modification operations maintain ordering.
A struct for rational numbers

// A rational number num/den
struct Rational
{
    long num;
    long den;
};
Rational representation issues

There are some issues with representing rational numbers:

• Do Rational {2, 3} and Rational {4, 6} represent the same number?

• What about Rational {2, 3} and Rational {-2, -3}?

• What does Rational {5, 0} mean?
Rational representation issues

There are some issues with representing rational numbers:

- Do \( \text{Rational}\{2, 3\} \) and \( \text{Rational}\{4, 6\} \) represent the same number?
Rational representation issues

There are some issues with representing rational numbers:

- Do $\text{Rational}\{2, 3\}$ and $\text{Rational}\{4, 6\}$ represent the same number?
- What about $\text{Rational}\{2, 3\}$ and $\text{Rational}\{-2, -3\}$?
There are some issues with representing rational numbers:

- Do $\text{Rational}\{2, 3\}$ and $\text{Rational}\{4, 6\}$ represent the same number?
- What about $\text{Rational}\{2, 3\}$ and $\text{Rational}\{-2, -3\}$?
- What does $\text{Rational}\{5, 0\}$ mean?
Solution: **Rational** struct invariants

For any `Rational r`,

- `r.den > 0`
- `gcd(r.num, r.den) == 1`
Solution: **Rational** struct invariants

For any **Rational** \( r \),

- \( r.\text{den} > 0 \)
- \( \gcd(r.\text{num}, r.\text{den}) == 1 \)

These two conditions ensure that:

- We don’t have nonsense rationals like **Rational**\{5, 0\}.
- Every representable rational number has exactly one representation.