Invariants and Encapsulation

EECS 211

Winter 2018
A struct encapsulating a binary search tree

```
struct Tree
{
    struct Node;
    using link_t = std::shared_ptr<Node>;
    struct Node
    {
        std::string key;
        unsigned value;
        link_t left;
        link_t right;
    };
    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
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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 \( \text{Rational} \{2, 3\} \) 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?
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Solution: Rational struct invariants

For any `Rational r`,

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

For any Rational $r$,

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

These two conditions ensure that:

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