Invariants and Encapsulation

EECS 211

Winter 2018
A struct encapsulating a binary search tree

```cpp
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 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,

- \texttt{t.size} needs to equal the actual number of elements
- For every node \texttt{n}, all the keys of \texttt{n.left} must be less than \texttt{n.key}
- For every node \texttt{n}, all the keys of \texttt{n.right} must be greater than \texttt{n.key}
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Then:

- Operations that need to know the size can safely use \texttt{t.size}.
- Operations that modify need to maintain \texttt{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;
};
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?
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Solution: Rational struct invariants

For any Rational r,

- $r.den > 0$
- $\gcd(r.num, r.den) == 1$
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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! –