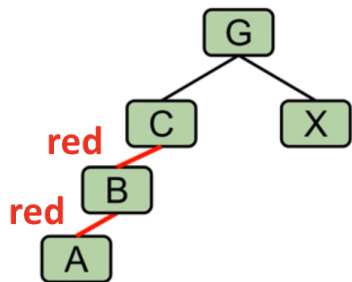


Section 04: Trees and Isomorphism

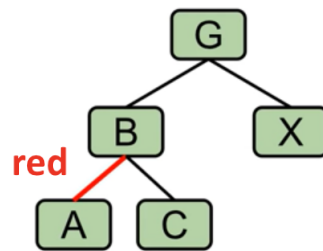
1. LLRBs and Validity

Are any of the following LLRB trees valid? Why or why not?

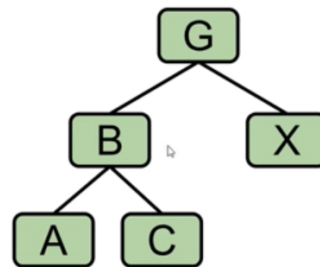
a)



b)



c)



a)

b)

c)

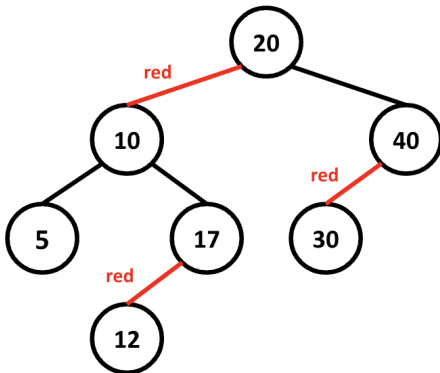
2. Isomorphism

Isomorphism means a one-to-one correspondence.

Since 2-3 Trees and LLRBs are **isomorphic**, we can convert a 2-3 Tree to its LLRB and vice versa!

Draw the left-leaning red-black tree that results after calling insert(25) using both of the following approaches.

- (a) **LLRB tree approach:** Insert 25 directly into the LLRB, connecting its invariants back to the 2-3 tree. Draw out the state of the LLRB tree after each flip or rotation.
- (b) **2-3 tree approach:** Draw out the process of inserting 25 into the equivalent 2-3 tree. Then, convert the resulting 2-3 tree back into an LLRB tree.



3. Design Malicious Website Tracker

Kevin is working at an internet security company and wants to keep track of malicious websites that users have reported. Websites are represented by a `String` URL.

Kevin wants to find common domain patterns (such as “.com” and “.org”) in the urls of malicious websites. Additionally, Kevin wants to support international domain names, which may contain unicode characters (such as “.भारत” or “.한국”).

NOTE: Suppose Kevin values space efficiency the most and is willing to sacrifice speed.

Kevin designs an ADT with the following functionality:

public void addURL(String url)

- Adds a malicious website url into the collection of reported urls

public int searchForSuffix(String suffix)

- Returns the total count of URLs ending with the specified suffix.

For example, suppose the following urls have been added:

```
addURL("washington.edu")
```

```
addURL("evilsite.com")
```

```
addURL("notNetflix.com")
```

```
addURL("korea.한국")
```

```
addURL("government.org")
```

Then `searchForSuffix(".com")` would return 2

Suppose URL inputs will be reasonable and that Kevin only cares about domain suffixes.

Design an efficient solution to support this ADT.

Hint: What data should a node store as fields?

Use this paper for any additional scratch work.