1. Draw the keyword tree for \( P = \{\text{potato, tattoo, theater, other}\} \) and include the non-trivial (non-root) failure links
   - Draw the suffix tree for \( T = \text{“banana”} \). Add suffix links and show the edge label compression.
   - Show the sequence of explicit extensions the Ukkonen algorithm uses for constructing the suffix tree in 2.

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Adding failure links

- Two nodes \( u, v, u \neq v \)
- Node labels \( L(u), L(v) \)
- Suffix of \( L(u) \), \( S(L(u)) = L(v) \)
- Links:
  \[
  \max_{v \in T} L(v) = S(L(u))
  \]
Add suffix links

- Links between internal nodes u, v
- Node labels L(u), L(v)
- Suffix link (u, s(u)) = (u, v) iff
  - L(u) = xα
  - L(v) = α

#?

Adding suffix links

Add edge label compression

- Index pairs to label edges
  - Start and end in T
- T = banana$

1. Draw the keyword tree for $P = \{\text{potato, tattoo, theater, other}\}$ and include the non-trivial (non-root) failure links
2. Draw the suffix tree for $T = \text{"banana"}$. Add suffix links and show the edge label compression.
3. Show the sequence of explicit extensions the Ukkonen algorithm uses for constructing the suffix tree in 2.
High level suffix extension (Ukkonen) algorithm

HighLevelUkkonen(T):
  1. Construct tree I
  2. for i in range(|T| - 1):
     1. for j in range(i + 1):
        1. Find end of path labeled T[j:i] in I
        2. Extend that path by T[i + 1] if needed
  Total: O(|T|)

Running time
  1. O(1)
  2. |T| = m
     1. i times
     2. O(i + 1 – j)
  Total: O(|T|)

Three suffix extension rules

- T[i:j] = \beta is suffix of T[1:i]
- End of \beta found, extend such that |T[1:j]| is in tree
  1. \beta ends at leaf
     - Append T[1:j] to label
  2. No path from end of \beta starts with T[1:j], but path continues
     - Create new leaf edge from end of \beta and label with T[1:j]
     - Number leaf with j
  3. Tree contains |T[1:j]|
     - Do nothing

Single phase algorithm (SPA)

  1. \( e = i + 1 \)
  2. for j in range(i + 1, i + 1):
     1. Use SingleExtensionAlgorithm for explicit extensions
     2. if “rule 3” applies:
        1. break
  3. \( j_{i+1} = j - 1 \)

Ukkonen suffix tree construction

Rule 2

Rule 3
Contents of implicit tree at $i = 7$

Need explicit extensions:

Explicit extensions at $i = 7$ continued