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.
   - Ukkonen construction of suffix tree for $T = \text{"rerirra"}$

---

**Adding failure links**

- Two nodes $u, v, u \neq v$
- Node labels $L(u), L(v)$
- Suffix of $L(u)$, $S_i(L(u)) = L(v)$
- Links:
  $$ \max \{L(v) - S_i(L(u)) : i \geq 0\} $$

---

**P = \{potato, tattoo, theater, other\}**

- Ukkonen construction of suffix tree for $T = \text{"rerirra"}$
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$

Draw the keyword tree for $P = \{\text{potato}, \text{tattoo}, \text{theater}, \text{other}\}$ 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.

- Ukkonen construction of suffix tree for $T = \text{"rrerirra"}
High level suffix extension (Ukkonen) algorithm

**HighLevelUkkonen(T):**
1. Construct tree $I_1$
2. for $i$ in range($|T| - 1$):
   1. Find end of path labeled $T[j:i]$ in $I_i$
   2. Extend that path by $T[i+1]$ if needed

**Running time**
1. $O(1)$
2. $|T| = m$
   1. $i$ times
   2. $O(i + 1 - j)$
   2. $O(1)$

**Total:** $O($____$)$

---

Three suffix extension rules

- $T[j:i] = \beta$ is suffix of $T[1:i]$
- End of $\beta$ found, extend such that $|\beta|+1$ is in tree
  1. $\beta$ ends at leaf
     - Append $T[i+1]$ to label
  2. No path from end of $\beta$ starts with $T[i+1]$, but path continues
     - Create new leaf edge from end of $\beta$ and label with $T[i+1]$
     - Number leaf with $j$
  3. Tree contains $|\beta|+1$
     - 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

<table>
<thead>
<tr>
<th>Phase i</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase i=1</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
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<td>12</td>
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<td>14</td>
<td>15</td>
<td>16</td>
</tr>
<tr>
<td>Phase i=2</td>
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<td>13</td>
<td>14</td>
<td>15</td>
<td>16</td>
</tr>
<tr>
<td>Phase i=3</td>
<td>1</td>
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<td>12</td>
<td>13</td>
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<td>15</td>
<td>16</td>
</tr>
</tbody>
</table>

Rule 2

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Rule 2

---

Rule ____

---

Rule __

---

Rule __

---

Rule ___

---

Rule ___

---
1. Draw the keyword tree for \( P = \{ \text{potato, tattoo, theater, other} \} \) and include the non-trivial (non-root) failure links.
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- Ukkonen construction of suffix tree for \( T = \text{"rrerirra"} \)
Suffix tree for rrerirra

Gamma ___? Rules ___?