Cairo University
Faculty of Computers and Artificial Intelligence
Computer Science Department

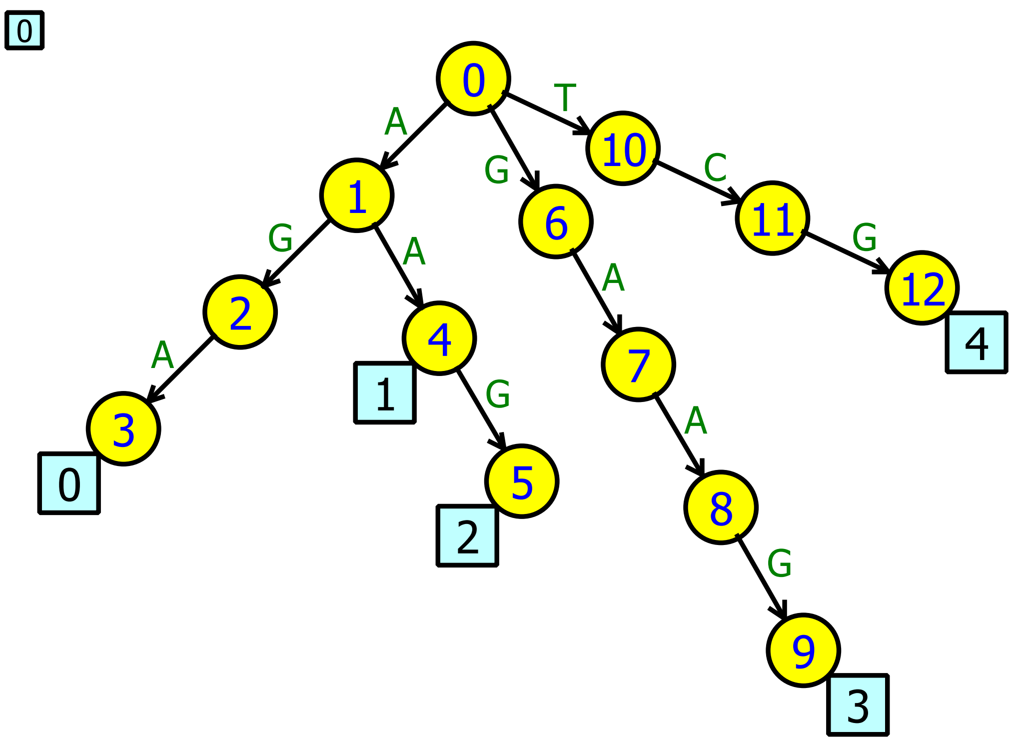
Biological sequence analysis
BIO456

Aho-Corasick Algorithm

Dr. Amin Allam

1 Failure links automaton

The Aho-Corasick algorithm allows efficient searching for multiple patterns in non-indexed strings. The first step in the Aho-Corasick algorithm is to construct the failure links automaton for the patterns that we need to search for. The following animated figure explains how to construct the failure links automaton for the patterns { `AGA`, `AA`, `AAG`, `GAAG`, `TCG` }. Each mouse click on the following animation moves one step:



Node 0 does not have a failure link
because it is the root

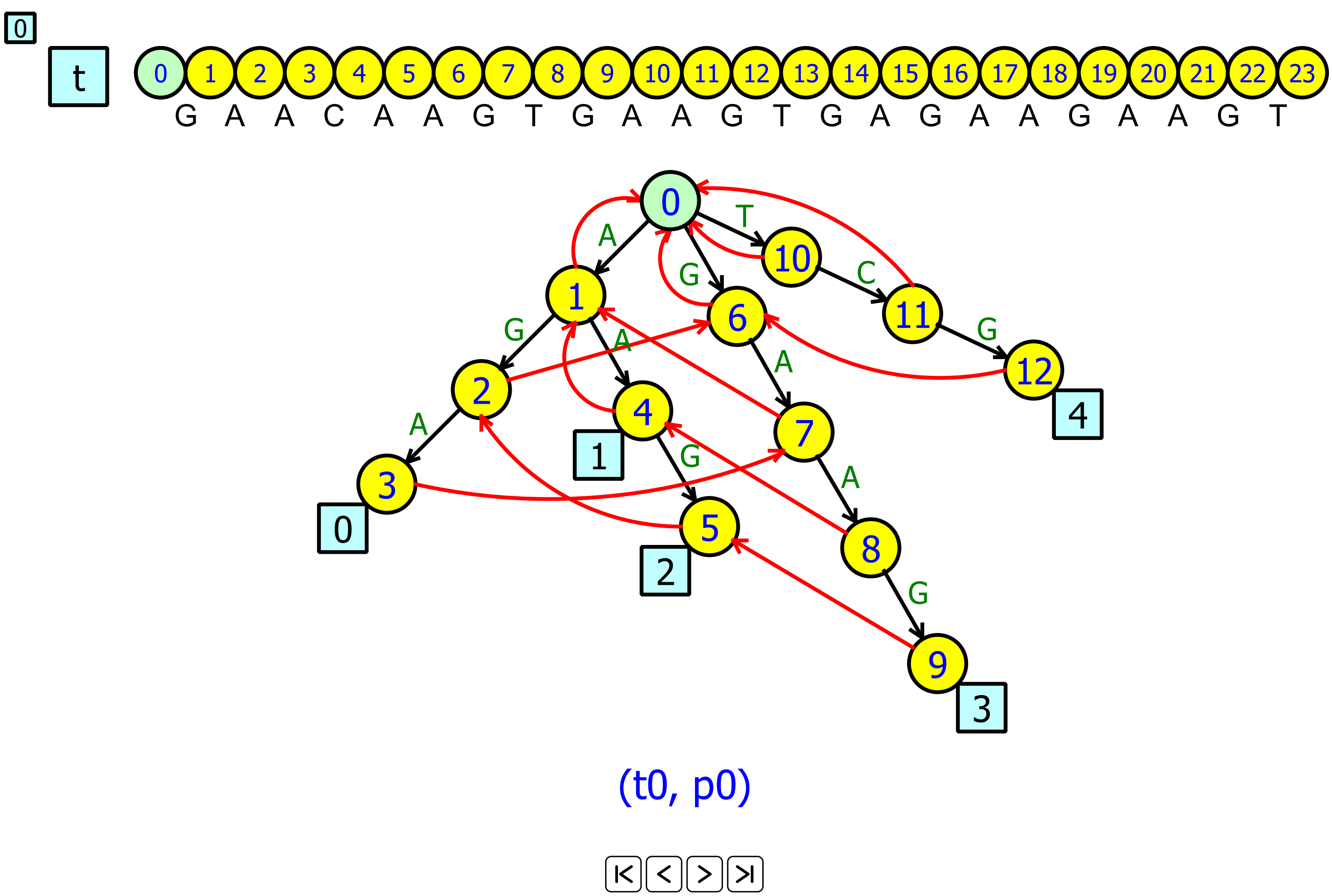
To construct the failure links automaton of the patterns that we need to search for, we start by constructing the trie which corresponds to these patterns. Then for each node p_i other than the root node p_0, construct a failure link that starts from node p_i and goes to another node as follows:

Consider the string s_i labeling edges on the path from the root node p_0 to node p_i. The failure link starting at node p_i must end at node p_j, where p_j is the location of the string s_j in the trie, where s_j is the longest proper suffix of s_i that has a location in the trie (it is possible to traverse the trie starting from root using s_j). If no such suffix exists, the failure link starting from node p_i must end at the root node p_0.

For example, to find the destination of the failure link starting from node p_8, consider the string GAA which starts from the root node p_0 and ends at node p_5. The proper suffixes of that string, ordered from longest to shortest, are: (AA, A). The longest proper suffix of these 2 suffixes that also has a location in trie starting from p_0 is AA. Since starting from p_0 the suffix AA ends at trie node p_4, the failure link starting from node p_8 must end at node p_4.

2 Aho-Corasick algorithm

The following animated figure is an example of applying the Aho-Corasick algorithm to search for the patterns { AGA, AA, AAG, GAAG, TCG } inside the text GAACAAGTGAAGTGAGAAGAAGT. Each mouse click on the following animation moves one step:



To search for a set of patterns P in text t of size $|t|$, the Aho-Corasick algorithm proceeds as follows: Construct the failure links automaton of P. Construct a simple automaton for text t without failure links. The algorithm keeps track of two nodes: a node in the automaton of t and another node in the automaton of P. The algorithms starts from the state (t_0, p_0) which are the initial node in the t and the root of p automata. The algorithm terminates when it reaches the state $(t_{|t|}, p_0)$.

Suppose the algorithm is at state (t_i, p_j):
• If the edges $t_i \rightarrow t_{i+1}$ and $p_j \rightarrow p_{j+1}$ have equal labeling characters, go to (t_{i+1}, p_{j+1}). Then report an occurrence of the pattern ending at node p_{j+1} (if exists) starting from t_{i-plen} where $plen$ is the size of the pattern ending at p_{j+1}. Also, report all patterns ending at the nodes on the failure links path starting from p_{j+1} and ending at p_0.
• Otherwise:
  • If $j = 0$, go to (t_{i+1}, p_j).
  • Otherwise, go to $(t_i, f[p_j])$, where $f[p_j]$ is the destination node of the failure link of node p_j.

The complexity of the Aho-Corasick algorithm is $O(|t|+k|p|)$ (plus the number of reported pattern occurrences), where k is the number of patterns and $|p|$ is the average size of one pattern. This is asymptotically better than applying the KMP algorithm k times on the k patterns which has the complexity $O(k \times (|t| + |p|)) = O(k|t| + k|p|)$ For official proofs regarding the correctness and complexity of the Aho-Corasick algorithm, consult the reference text book.