Parsing Natural Language

Parsing Without Grammar: Shift-Reduce Dependency Parsing

Parsing: Schematics

- So far, we considered algorithms that used a grammar to only produce „valid“ trees
- In this lecture, we are using machine-learning to directly produce a parse-tree, without relying on a grammar
  - This means our output can be super unintuitive, since it is not guide by a grammar, but we are able to incorporate strong features into the process!
- Two famous approaches:
  1. Shift-Reduce-Parsing
  2. Graph-based parsing

Shift-Reduce-Parsing

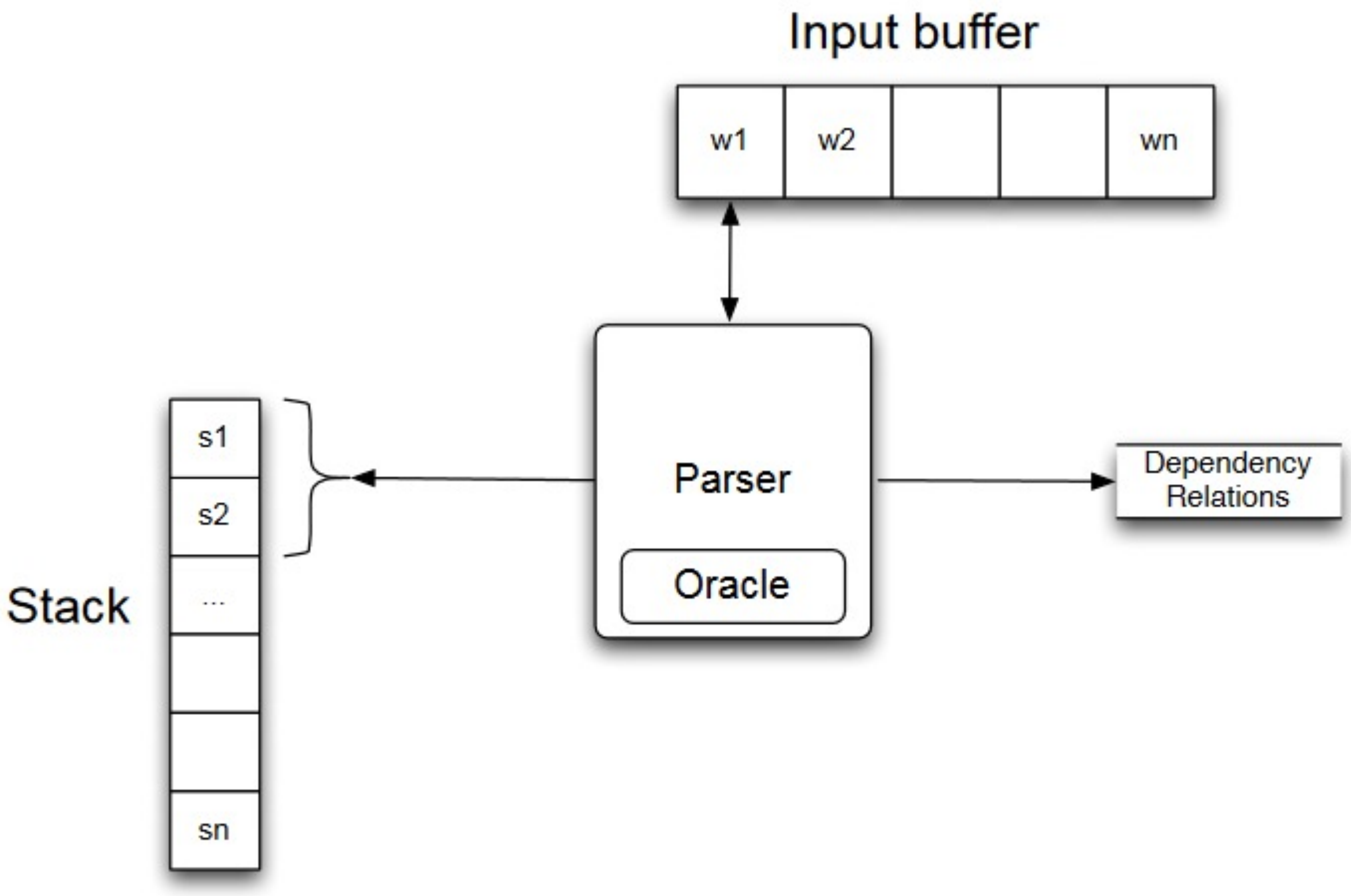
- Origins in parsing computer languages
- Makes use of a very clever data structure to deal with this problem
- Only difference to a classical parser for computer language is the addition of an „oracle“

- Usually used for Dependency Parsing problems!

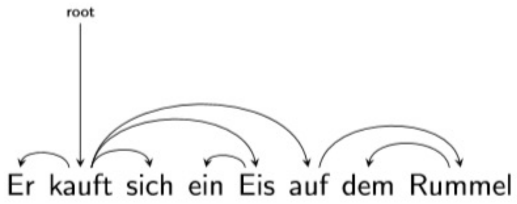
Shift-Reduce-Parsing

- Makes use of a very clever data structure to deal with this problem
- The clever idea, is that we can convert the problem of producing a tree into a classification problem with just 3 classes!
- This works by the introduction of a Buffer and a Stack! (see next slide)

Dependency-Parsing: Data structure



Shift Reduce Parsing



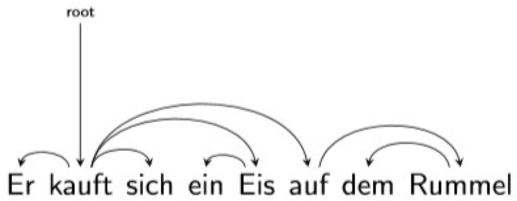
He buys an ice cream at the carnival

Stack

Buffer

root Er kauft sich ein Eis auf dem Rummel

Shift Reduce Parsing



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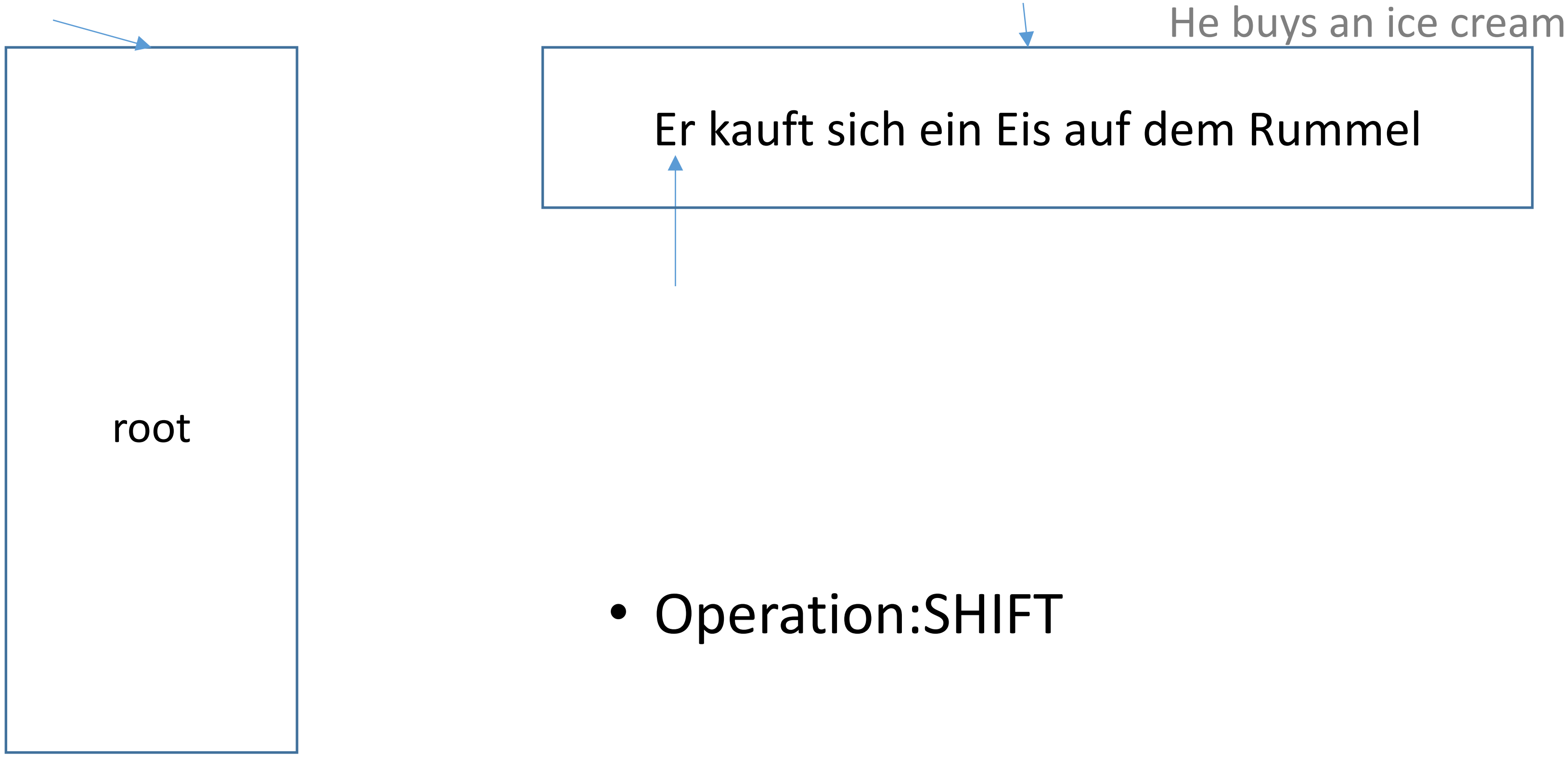
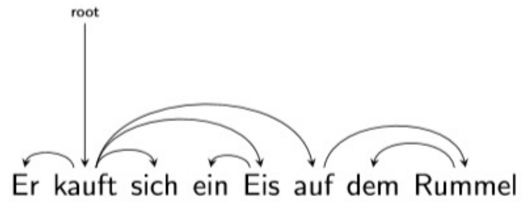


root

Er kauft sich ein Eis auf dem Rummel

- Operation:SHIFT

Shift Reduce Parsing



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Stack

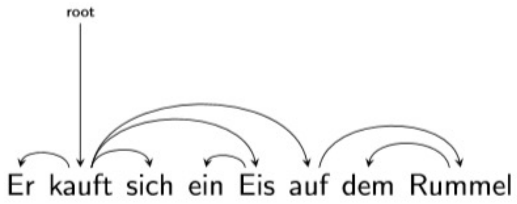
Er
root

Buffer

kauft sich ein Eis auf dem Rummel

- Operation:SHIFT

Shift Reduce Parsing



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Stack

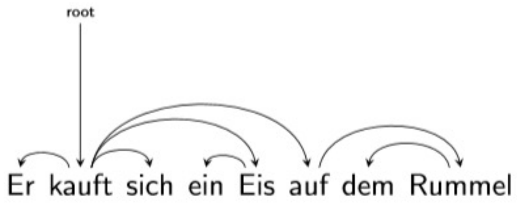
Buffer

sich ein Eis auf dem Rummel

kauft
Er
root

- Operation:SHIFT

Shift Reduce Parsing



He buys an ice cream at the carnival

Stack

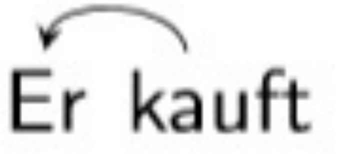
kauft
~~Er~~
root

Buffer

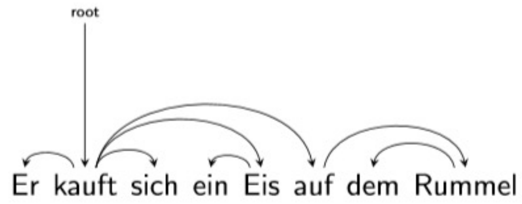
sich ein Eis auf dem Rummel

- Operation:LEFTARC

- Result:



Shift Reduce Parsing



He buys an ice cream at the carnival

Stack

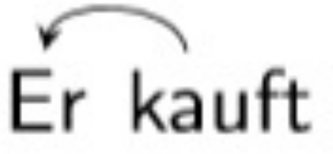
sich
kauft
root

Buffer

ein Eis auf dem Rummel

- Operation:SHIFT

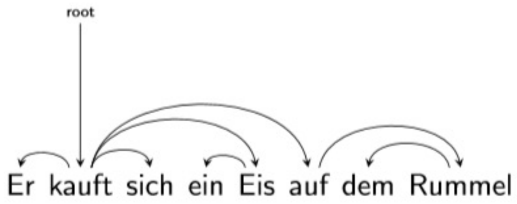
- Result:



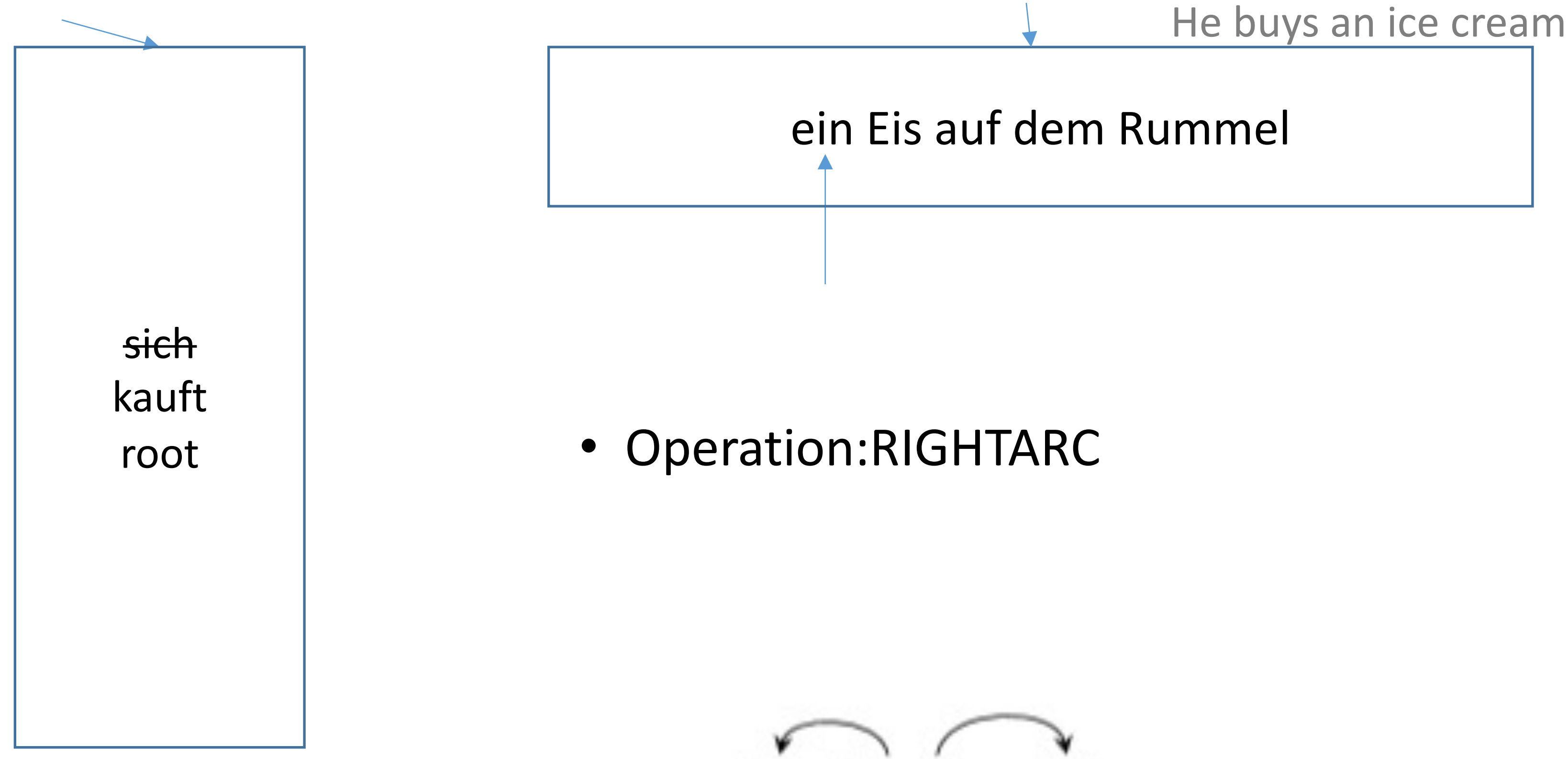
Shift Reduce Parsing

Stack

Buffer



He buys an ice cream at the carnival

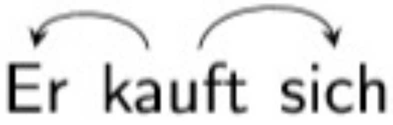


~~sich~~
kauft
root

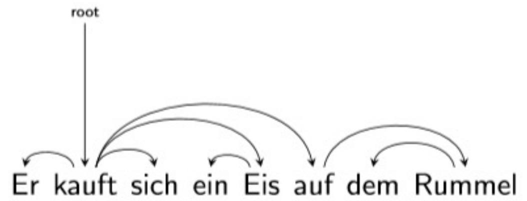
ein Eis auf dem Rummel

- Operation:RIGHTARC

- Result:



Shift Reduce Parsing



He buys an ice cream at the carnival

Stack

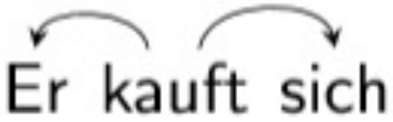
ein
kauft
root

Buffer

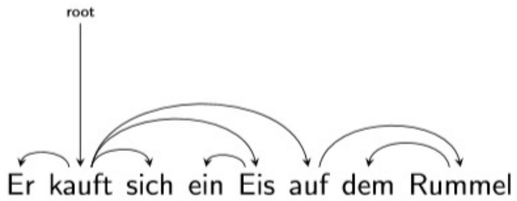
Eis auf dem Rummel

- Operation:SHIFT

- Result:



Shift Reduce Parsing



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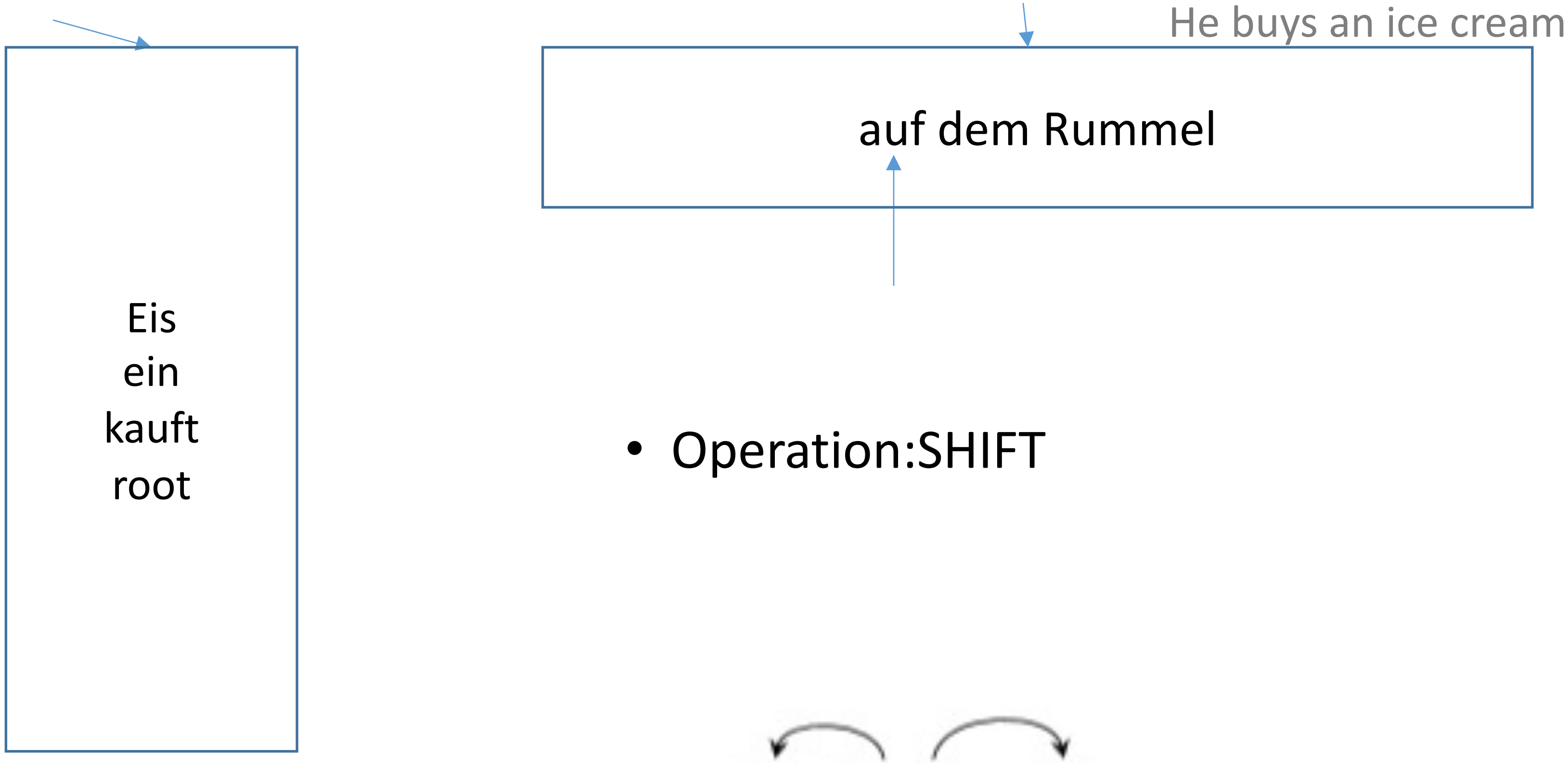
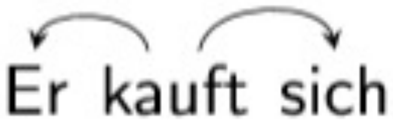
Stack

Buffer

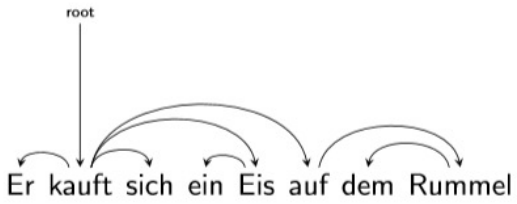


- Operation:SHIFT

- Result:



Shift Reduce Parsing



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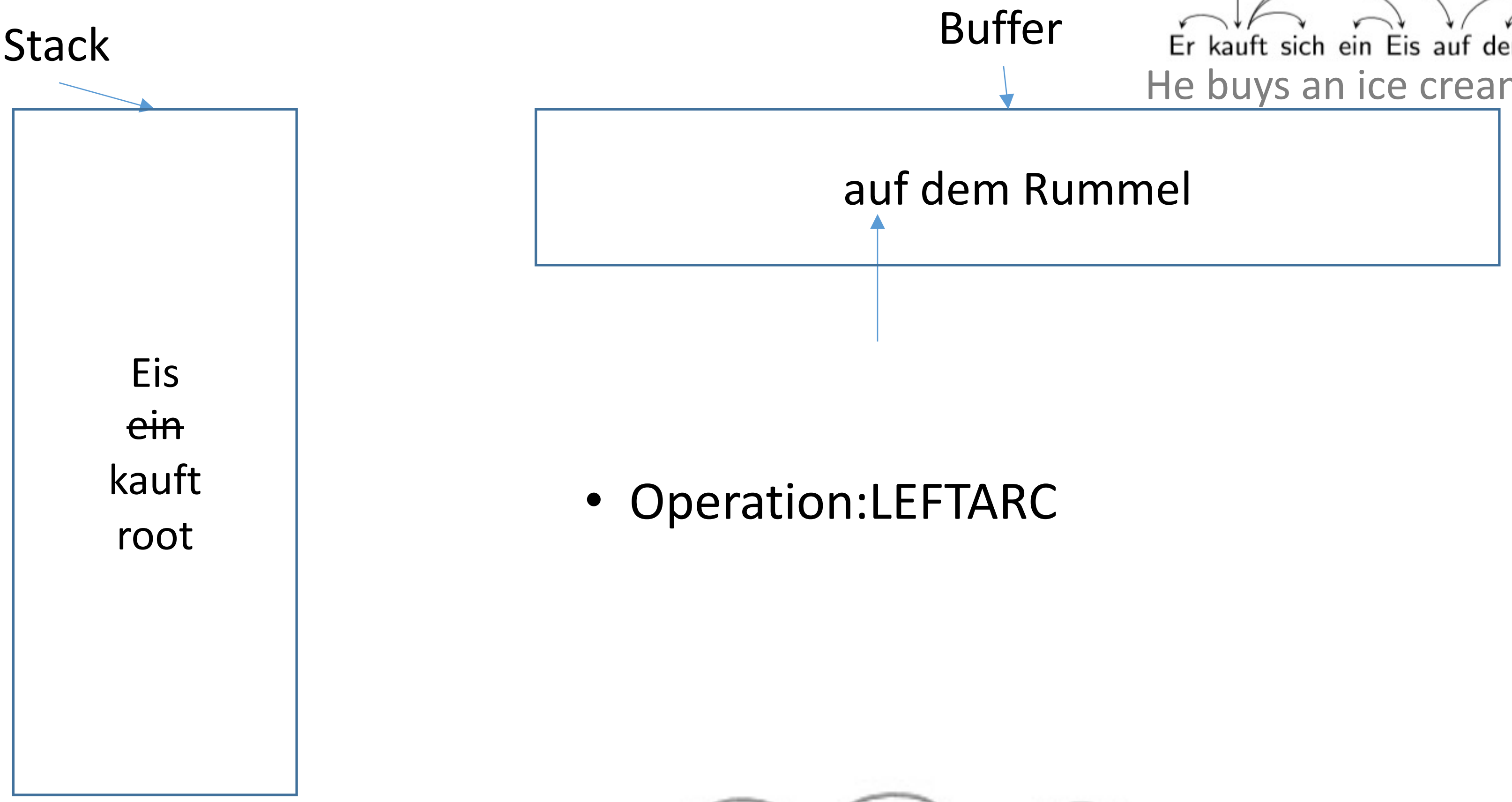
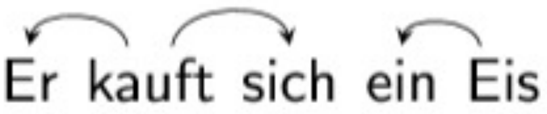


auf dem Rummel

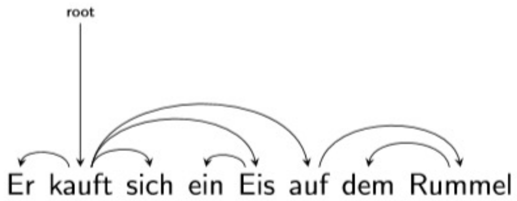
Eis
~~ein~~
kauft
root

- Operation:LEFTARC

- Result:



Shift Reduce Parsing



He buys an ice cream at the carnival

Stack

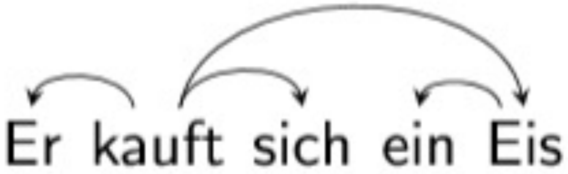
Buffer

auf dem Rummel

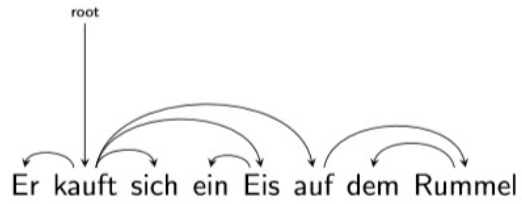
~~Eis~~
kauft
root

- Operation:RIGHTARC

- Result:



Shift Reduce Parsing



He buys an ice cream at the carnival

Stack

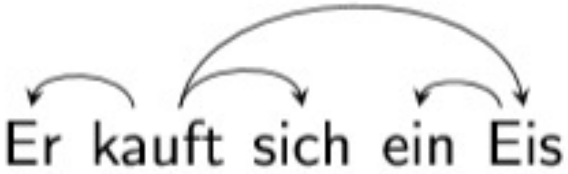
auf
kauft
root

Buffer

dem Rummel

- Operation:SHIFT

- Result:



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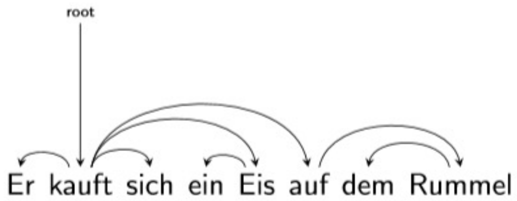
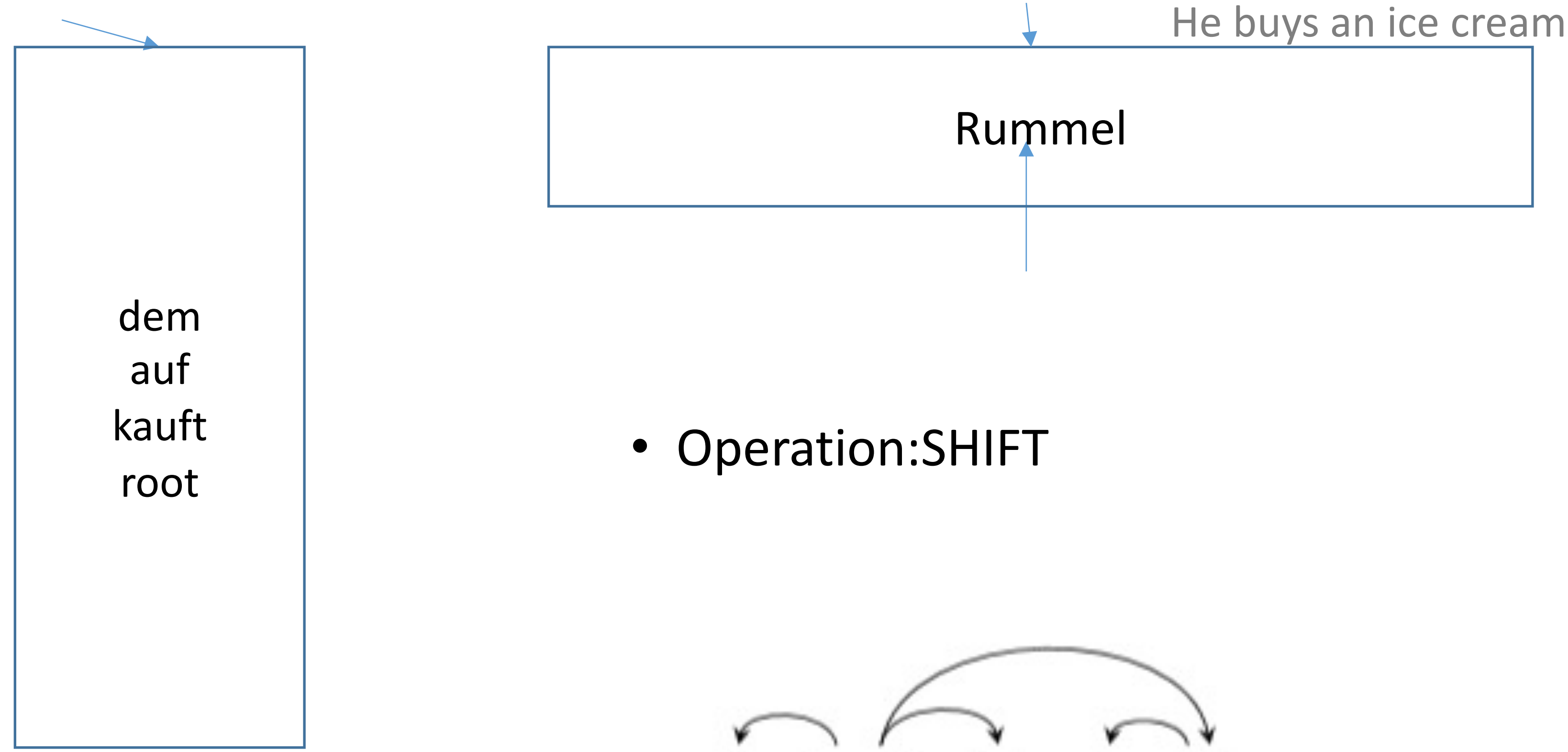


He buys an ice cream at the carnival

Stack

Buffer

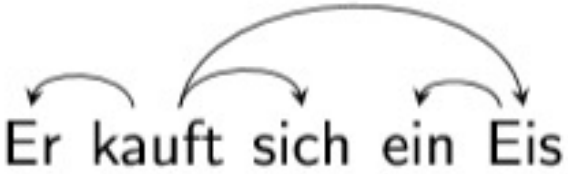


Rummel

dem
auf
kauft
root

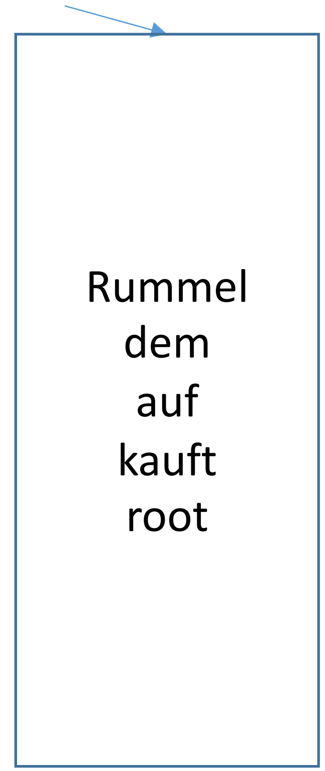
- Operation:SHIFT

- Result:



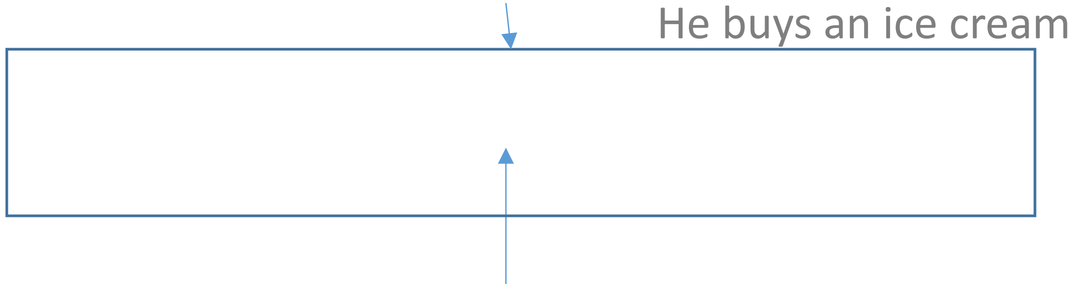
Shift Reduce Parsing

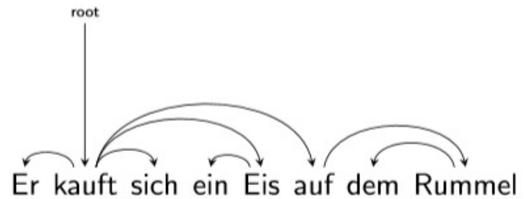
Stack



Rummel
dem
auf
kauft
root

Buffer

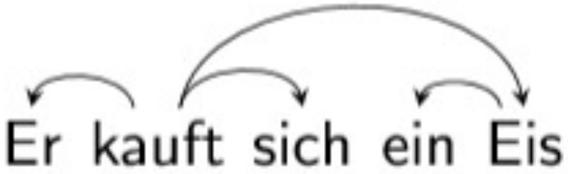




He buys an ice cream at the carnival

- Operation:SHIFT

- Result:



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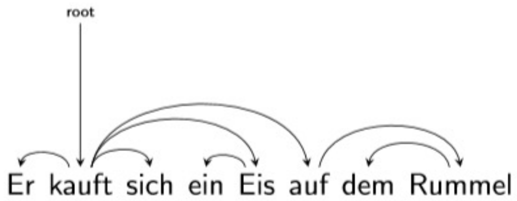


He buys an ice cream at the carnival

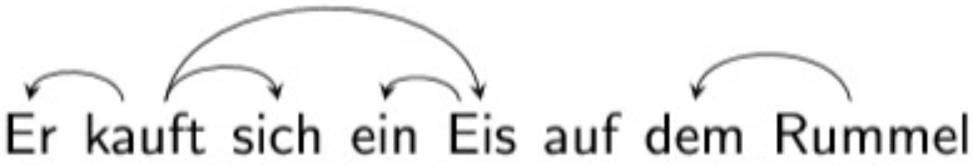
Stack

Buffer

Rummel
~~dem~~
auf
kauft
root

- Operation:LEFTARC

- Result:



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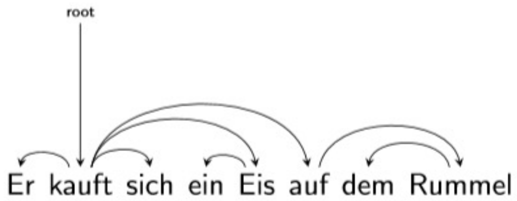


He buys an ice cream at the carnival

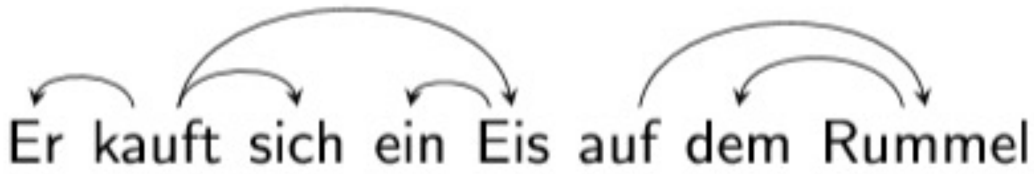
Stack

Buffer

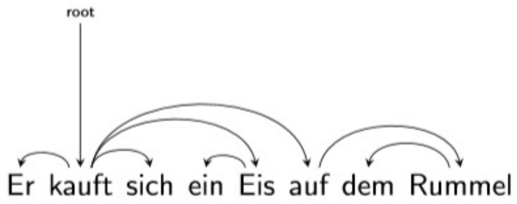
~~Rummel~~
auf
kauft
root

- Operation:RIGHTARC

- Result:



Shift Reduce Parsing



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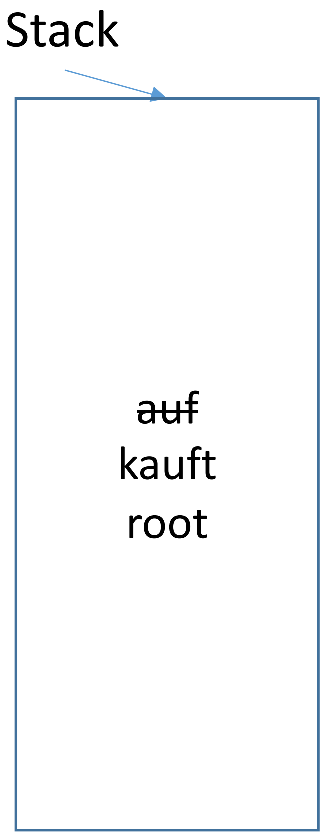
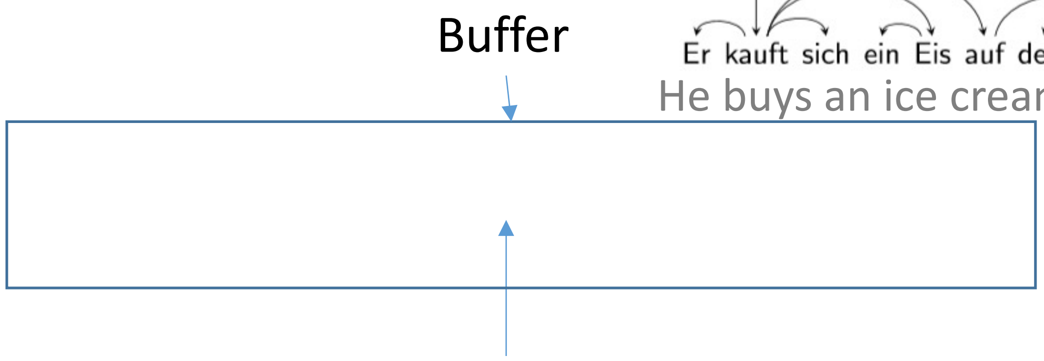
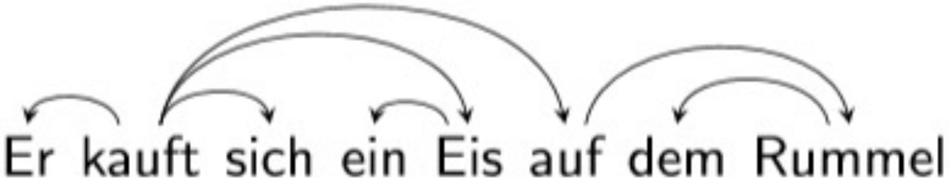


~~auf~~
kauft
root



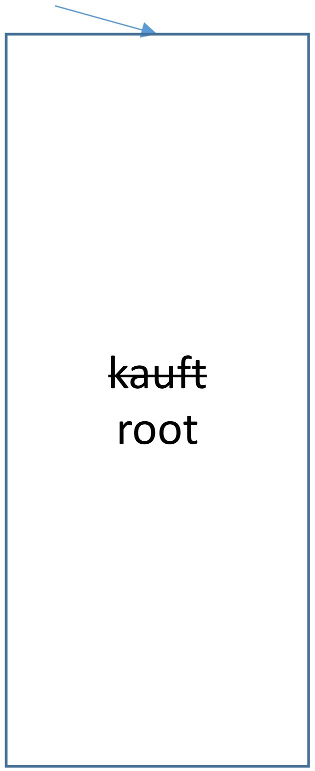
- Operation:RIGHTARC

- Result:



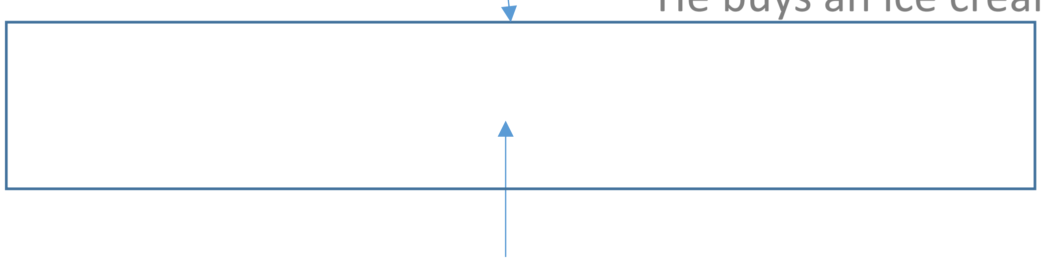
Shift Reduce Parsing

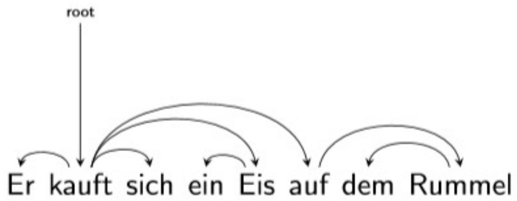
Stack



~~kauft~~
root

Buffer

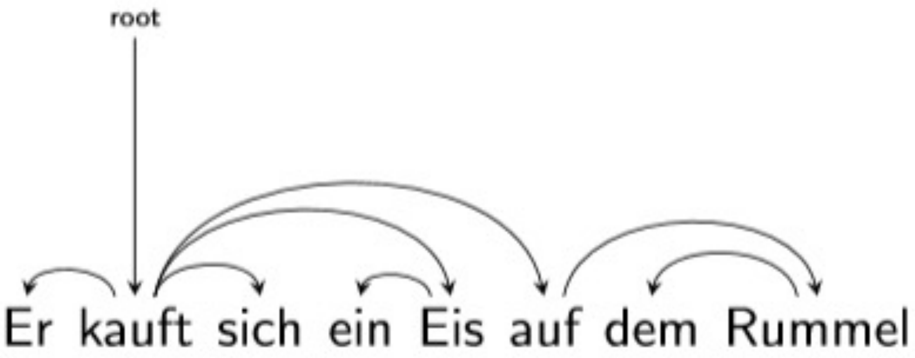




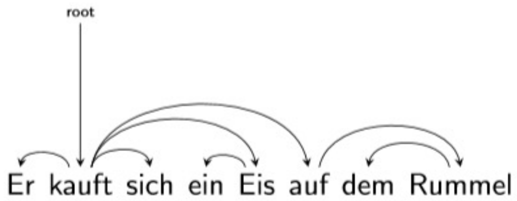
He buys an ice cream at the carnival

- Operation:RIGHTARC

- Result:



Shift Reduce Parsing



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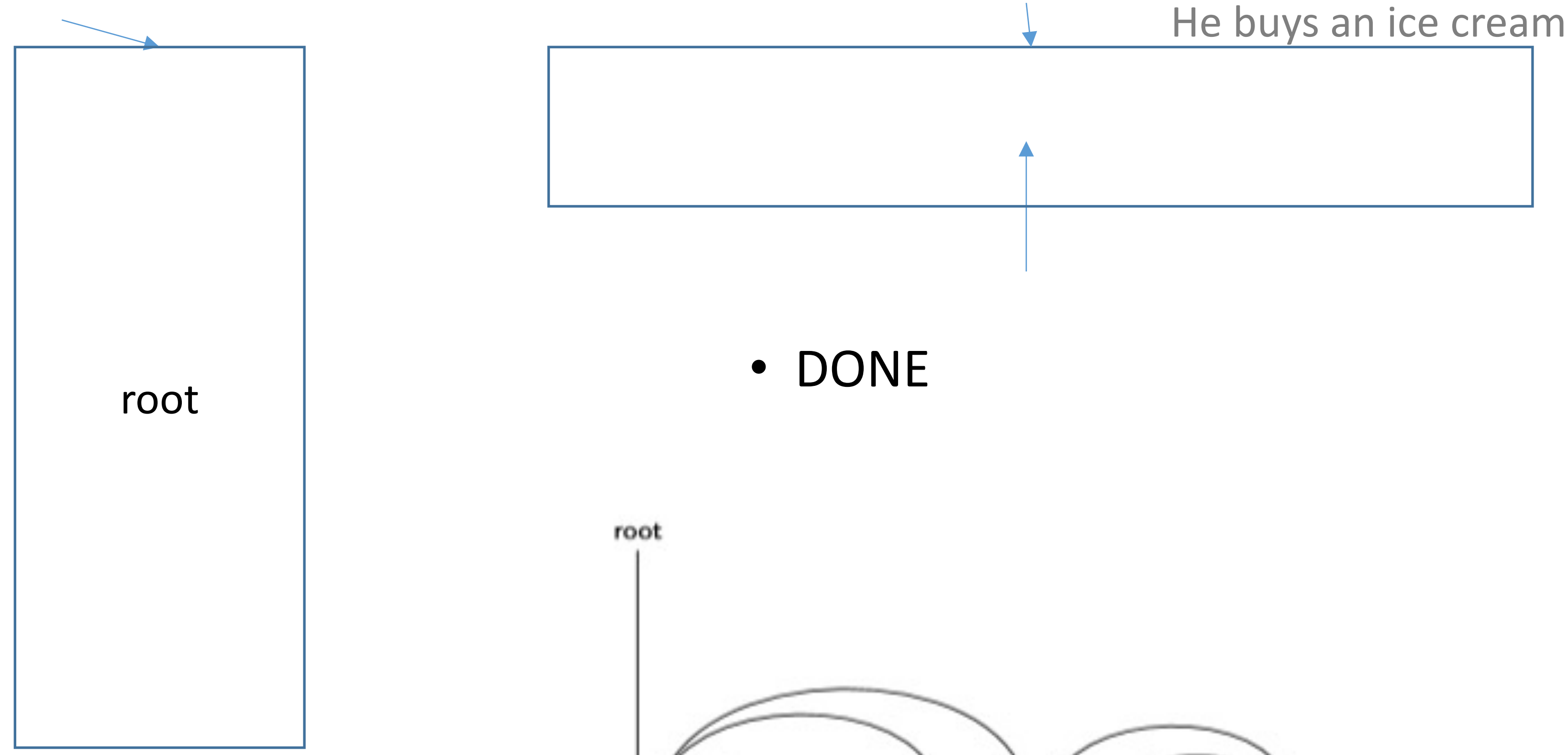
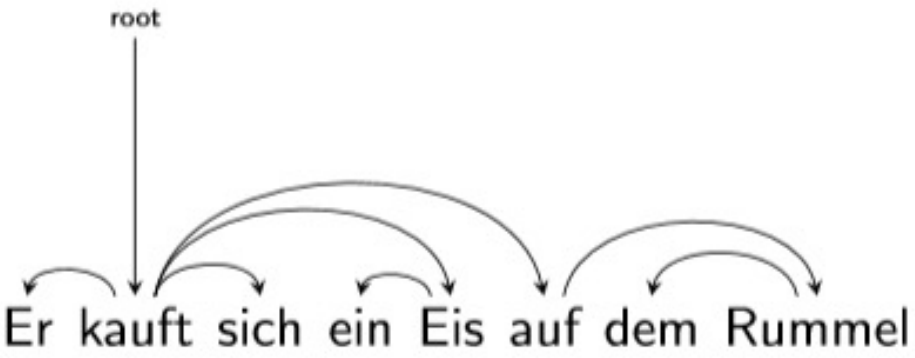
Stack

Buffer



- DONE

- Result:



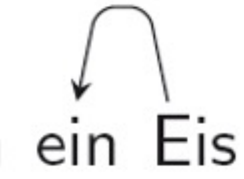
Shift Reduce Parsing: Arc Standard

- How to use this for Dependency Parsing?

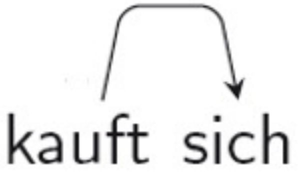
➔Use an adjusted set of operations!

➔ Arc-Standard

1. **LEFTARC**: Add an edge between the first token of the stack and the second token of the stack. Delete the second token from the stack

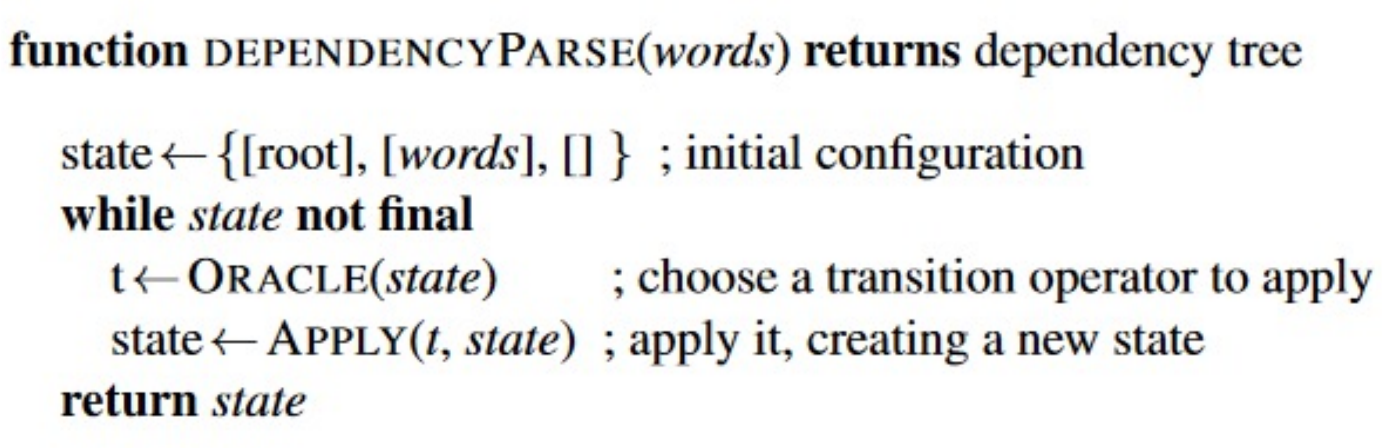


2. **RIGHTARC**: Add an edge between the second token of the stack and the first token of the stack. Delete the first token from the stack.



3. **SHIFT**: Move the first token from the buffer onto the stack

Dependency Parsing – Greedy Parse



```
function DEPENDENCYPARSE(words) returns dependency tree

  state ← {[root], [words], [] }  ; initial configuration
  while state not final
    t ← ORACLE(state)          ; choose a transition operator to apply
    state ← APPLY(t, state)  ; apply it, creating a new state
  return state
```

Dependency Parsing – Oracle

- Features:
  - Use arbitrary features from the stack, the buffer, or the edges we produced already

  - Usually features are of the sort:
    - text of Stack[0] and operation $< s_0.text, op >$
    - Text Stack[1] und operation $< s_1.text, op >$
    - POS-Tag of Stack[0] and operation $< s_0.pos, op >$
    - POS-Tag Stack[1] and operation $< s_1.pos, op >$
    - text of Buffer[0] and operation $< b_0.text, op >$
    - Text Buffer[1] and operation $< b_1.text, op >$
    - POS-Tag of Buffer[0] and operation $< b_0.pos, op >$
    - POS-Tag Buffer[1] und operation $< b_1.pos, op >$
    - …

Recap: Shift Reduce Parsing

- Grammarless way of parsing, but it relies on the quality of its oracle
- Any classifier can be used as an oracle (e.g. SVM, MaxEnt)
- Makes use of a clever data structure consisting of a stack and a buffer
- Input is the sentence, split into tokens
- Output is the set of operations:
    - Which is also the main way of adapting this kind of parser, you could add more operations (e.g. a SWAP)
- If you want to train such a classifier, you have to convert the tree bank into a suitable sequence of operations beforehand.
- If you want to predict Dependency-Relations, you just add them to the Operations: LEFTARC and RIGHTARC

➔ Greedy parsing has a linear runtime $O(n)$, with n tokens in the sentence