UNIVERSITETET I OSLO
Institutt for Informatikk

Reliable Systems
Martin Steffen

INF 5110: Compiler construction

Spring 2023

Handout 2

30. 01. 2023

Handout 2: Scanning etc.

Issued: 30. 01. 2023

The handout collects definitions in connection with scanning resp. the underlying principles and definitions. They are shown in the slides, as well, but collected in this handout for easier reference.

Definition 1 (Alpabet Σ) Finite set of elements called "letters" or "symbols" or "characters".

Definition 2 (Words and languages) Given an alphabet Σ, a *word* over Σ is a finite sequence of letters from Σ. A *language* over alphabet Σ is a *set* of finite *words* over Σ.

Definition 3 (Regular expressions) A *regular expression* is one of the following

1. a *basic* regular expression of the form $\mathbf{a}$ (with $a \in \Sigma$), or $\boldsymbol{\epsilon}$, or $\boldsymbol{\emptyset}$
2. an expression of the form $r \mid s$, where r and s are regular expressions.
3. an expression of the form $r\,s$, where r and s are regular expressions.
4. an expression of the form $r^{\boldsymbol{*}}$, where r is a regular expression.

Definition 4 (Regular expression) Given an alphabet Σ. The meaning of a regexp r (written $\mathcal{L}(r)$) over Σ is given by equation (1).

$$
\begin{array}{rcll}
\mathcal{L}(\boldsymbol{\emptyset}) & = & \{\} & \text{empty language} \\
\mathcal{L}(\boldsymbol{\epsilon}) & = & \{\epsilon\} & \text{empty word} \\
\mathcal{L}(\boldsymbol{a}) & = & \{a\} & \text{single ``letter'' from } \Sigma \\
\mathcal{L}(rs) & = & \{w_1 w_2 \mid w_1 \in \mathcal{L}(r), w_2 \in \mathcal{L}(s)\} & \text{concatenation} \\
\mathcal{L}(r \mid s) & = & \mathcal{L}(r) \cup \mathcal{L}(s) & \text{alternative} \\
\mathcal{L}(r^{\boldsymbol{*}}) & = & \mathcal{L}(r)^{*} & \text{iteration}
\end{array}
\tag{1}
$$

Definition 5 (FSA) A FSA $\mathcal{A}$ over an alphabet Σ is a tuple $(\Sigma, Q, I, F, \delta)$

- Q: finite set of states
- $I \subseteq Q$, $F \subseteq Q$: initial and final states.
- $\delta \subseteq Q \times \Sigma \times Q$ transition relation

Definition 6 (DFA) A *deterministic, finite automaton* $\mathcal{A}$ (DFA for short) over an alphabet Σ is a tuple $(\Sigma, Q, I, F, \delta)$

- Q: finite set of states
- $I = \{i\} \subseteq Q$, $F \subseteq Q$: initial and final states.
- $\delta : Q \times \Sigma \to Q$ transition function

Definition 7 (Accepted words and language of an automaton) A word $c_1 c_2 \ldots c_n$ with $c_i \in \Sigma$ is *accepted* by automaton $\mathcal{A}$ over Σ, if there exists states $q_0, q_2, \ldots, q_n$ from Q such that

$$q_0 \xrightarrow{c_1} q_1 \xrightarrow{c_2} q_2 \xrightarrow{c_3} \quad \ldots \quad q_{n-1} \xrightarrow{c_n} q_n \ ,$$

and were $q_0 \in I$ and $q_n \in F$. The *language* of an FSA $\mathcal{A}$, written $\mathcal{L}(\mathcal{A})$, is the set of all words that $\mathcal{A}$ accepts.

Definition 8 (NFA (with ϵ transitions)) A *non-deterministic* finite-state automaton (NFA for short) $\mathcal{A}$ over an alphabet Σ is a tuple $(\Sigma, Q, I, F, \delta)$, where

- Q: finite set of states
- $I \subseteq Q$, $F \subseteq Q$: initial and final states.
- $\delta : Q \times \Sigma \to 2^Q$ transition function

In case, one uses the alphabet $\Sigma + \{\epsilon\}$, one speaks about an NFA with ϵ-transitions.

Definition 9 (Acceptance with ϵ-transitions) A word w over alphabet Σ is *accepted* by an NFA with ϵ-transitions, if there exists a word w' which is accepted by the NFA with alphabet $\Sigma + \{\epsilon\}$ according to Definition 7 and where w is w' with all occurrences of ϵ removed.

Definition 10 (ϵ-closure, a-successors) Given a state q, the *ϵ-closure* of q, written $\mathit{close}_\epsilon(q)$, is the set of states reachable via zero, one, or more ϵ-transitions. We write q_a for the set of states, reachable from q with one a-transition. Both definitions are used analogously for sets of states.