Synthesized and inherited functions

A new computational model for syntax-directed semantics

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Abstract. In this paper we introduce a new formal model for the concept of syntax-directed semantics, called macro attributed tree transducer (for short: mat tree transducer). This model is based on (noncircular) attributed tree transducers and on macro tree transducers. In the first type of transducer, semantic values are computed by means of meaning names called synthesized attributes, and by means of context names called inherited attributes. Both, synthesized and inherited attributes represent basic semantic values. In the second type of transducer, semantic values are computed by meaning names only which are called states. However, in order to have a means of handling context information, states represent functions over semantic values. The new model integrates attributed tree transducers and macro tree transducers by allowing both, meaning names and context names to represent functions over semantic values. In analogy to the terminology of attributed tree transducers, we call such meaning names and context names also synthesized functions and inherited functions, respectively.

We present an inductive characterization of the tree transformation computed by an mat tree transducer. We prove that mat tree transducers are more powerful than both, attributed tree transducers and macro tree transducers. We characterize mat tree transducers by the two-fold composition of attributed tree transducers. This characterization has three consequences: (1) the height of output trees of mat tree transducers is bounded exponentially in the size of the input tree, (2) the composition hierarchy of mat tree transducers is strict, and (3) mat tree transducers are closed under right-composition with top-down tree transducers, but not under left-composition. Moreover, we prove that the addition of inherited attributes does not increase the computational power of macro tree transducers.

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1. Introduction

The concept of syntax-directed semantics is a well-accepted principle to describe the meaning of tree-structured objects. Since such objects will control the computation of the meanings, we will call them control trees. The concept of syntax-directed semantics was first formalized by E.T. Irons [Iro61] in 1961. In the meantime, many other formalizations of the concept have been studied, e.g., attribute grammars [Knu68], top-down tree transducers [Rou70, Tha70], generalized syntax-directed translation schemes [AU71, AU73], denotational semantics [SS71, Gor79], affix grammars [Kos71], macro tree transducers [Eng80, CF82, EV85], attributed tree transducers [Fül81], attribute coupled grammars [Gie88], context-free hypergraph-based syntax-directed translation schemes [EH91], and top-down tree-to-graph transducers [EV92]. A detailed study of the concept of syntax-directed semantics is given in [Eng81] where special attention is paid to the description and comparison of attribute grammars and macro tree transducers.

In most of the models which are mentioned, handling of context is possible. More precisely, if $s$ is a given control tree and $n$ is a node of $s$, then the models allow to express that the semantic values of different meaning names at $n$ may depend on information about the context of the subtree $\text{sub}(s, n)$ which starts at $n$ (cf. Fig. 1).

![Fig. 1. Control tree $s$, subtree $\text{sub}(s, n)$, and its context](image)

In particular this ability holds for attributed tree transducers and macro tree transducers. However, the context handling is formalized differently:

1. In attributed tree transducers, context names are explicitly associated with $n$; they carry the semantic values of the context information. Here, meaning names and context names are called synthesized attributes and inherited attributes, respectively. Both types of attributes represent basic semantic values.
2. In macro tree transducers, context information does not appear explicitly. Rather the meaning names of a node $n$ are formalized as functions which map semantic values of context information to the desired semantic values.

In this paper we introduce a new formalization of the concept of syntax-directed semantics, called macro attributed tree transducer (for short: mat tree transducer) which integrates the context handling mechanisms of (noncircular) attributed tree transducers and of macro tree transducers. In mat tree transducers, meaning names and context names are available, and both types of names represent functions over basic semantic values. In analogy to attributed tree transducers, we will call meaning names and context names synthesized functions and inherited functions, respectively.