Capture-Avoiding Program Transformations with \textit{name-fix}

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Abstract: We present an algorithm called name-fix that automatically eliminates variable capture from a generated program by systematically renaming variables. name-fix is guided by a graph representation of the binding structure of a program, and requires name-resolution algorithms for the source language and the target language of a transformation. name-fix is generic and works for arbitrary transformations in any transformation system that supports origin tracking for names.

Program transformations find ubiquitous application in compiler construction to realize desugarings, optimizers, and code generators. While traditionally the implementation of compilers was reserved for a selected few experts, the current trend of domain-specific and extensible programming languages exposes developers to the challenges of writing program transformations. In our paper [EvdSD14], we address one of these challenges: capture avoidance.

A program transformation translates programs from a source language to a target language. In doing so, many transformations reuse the names that occur in a source program to identify the corresponding artifacts generated in the target program. This bears the danger of variable capture where variables from the source program are captured by synthesized variable declarations or vice versa. In a study of current language workbenches, we found that developers in 8 out of 9 workbenches failed to address variable capture when implementing a simple domain-specific language [EvdSD14]. However, a general solution is difficult to obtain. Existing approaches either rely on naming conventions and fail to guarantee capture avoidance, or they require a specific transformation engine and affect the implementation of transformations [SB99, SPG03, LE13].

We propose a generic solution called name-fix that guarantees capture avoidance and does not affect the implementation of transformations. name-fix compares the name graph of the source program with the name graph of the generated program to identify variable capture. If there is variable capture, name-fix systematically and globally renames variable names to differentiate the captured variables from the capturing variables, while preserving intended variable references among original variables and among synthesized variables, respectively. name-fix requires name analyses for the source and target languages, which often exists or are needed anyway (e.g., for editor services, error checking, or refactoring), and hence can be reused. name-fix treats transformations as a black box and is independent of the used transformation engine as long as it supports origin tracking for names [VvdSE14, vDKT93].

name-fix enables developers of transformations to focus on the actual translation logic and to ignore variable capture. In particular, name-fix enables developers to use simple naming schemes for synthesized variables in the transformation and to produce intermediate open terms. Transformations of this kind fall into the class of transformations for which
name-fix guarantees hygiene, that is, \(\alpha\)-equivalent source programs are always mapped to \(\alpha\)-equivalent target programs.

Our current definition of name-fix renames not only synthesized names but also names that originate from the source program. This may break the expected interface of the generated code. Accordingly, name-fix currently is a whole-program transformation that does not support linking of generated programs against previously generated libraries, because names in these libraries cannot be changed. In order to apply name-fix in the context of our extensible programming language SugarJ [Erd13, ER13], we currently investigate a modular variant of name-fix that supports separate compilation.

Finally, the current implementation of name-fix requires repeated execution of the name analysis of the target language. As a result, name-fix can be expensive in terms of runtime performance. When a compiler is run continuously in an IDE, this penalty can be an impediment to usability. Fortunately, incrementality [MEK+14] and in particular incremental name analysis [RTD83, WKV+13] are well-studied topics that are likely to yield benefits for name-fix because (i) we know the delta induced by name-fix (renamed variables) and (ii) new variable capture can only occur in references that have changed.

References


