Untwisting two-way transducers in elementary time

Gabriele Puppis
CNRS – LaBRI

We consider finite transducers, namely, non-deterministic finite automata with outputs that compute functions or relations between words. Functional two-way transducers capture very nicely the notion of "regular" mappings from word to words, and they inherit many of the characterizations and algorithmic properties of the robust class of regular languages. For example, Engelfriet and Hoogeboom [EH01] showed that transformations of words defined by monadic second-order logic can be equivalently described by functional two-way transducers, in the same spirit as the classical results in logic and automata theory by Büchi, Elgot, Rabin and others. More recently, Alur and Cerný [AC10] proposed an enhanced version of one-way transducers, called streaming string transducers, and showed that they are equivalent to the relations definable in monadic second-order logic.

Two-way transducers raise challenging questions about resource requirements. One crucial resource is the number of times the transducer needs to re-process the input word. In particular, the case where the input can be processed in a single pass, from left to right, is very attractive as it corresponds to the setting of *stream processing*, where the (possibly very large) inputs do not need to be stored in order to be processed. Recently, it was shown in [FGRS13] that it is decidable whether the transduction defined by a functional two-way transducer can be implemented by a one-way transducer. However, the decision procedure of [FGRS13] has non-elementary complexity, and it is natural to ask whether one can do better.

I will present a selection of some recent results from [BGMP15, BGMP16, BGMP17], obtained in collaboration with Félix Baschenis, Anca Muscholl, and Olivier Gauwin, and related to the problem of deciding whether a function presented as a two-way transducer can be equally implemented by a one-way transducer. Specifically, there is an algorithm, of a different flavor than that of [FGRS13], that solves the one-way definability problem in elementary time (more precisely in 2ExpSpace). From the effective characterization one can also derive, in triple exponential time, an equivalent one-way transducer whenever it exists. I will also briefly discuss some natural generalizations of the one-way definability problem, notably, the problem of deciding whether a given transduction can be implemented by a sweeping transducer with either known or unknown number of passes (a sweeping transducer is one that performs reversals only at the extremities of the input word), and the problem of minimizing the number of registers in a given streaming string transducer.

References

[AC10] Rajeev Alur and Pavol Cerný. Expressiveness of streaming string transducers. In *FSTTCS*, volume 8 of *LIPIcs*, pages 1–12. Schloss Dagstuhl - Leibniz-Zentrum für Informatik, 2010.

[BGMP15] Félix Baschenis, Olivier Gauwin, Anca Muscholl, and Gabriele Puppis. One-way definability of sweeping transducer. In *FSTTCS*, volume 45 of *LIPIcs*, pages 178–191. Schloss Dagstuhl - Leibniz-Zentrum für Informatik, 2015.

[BGMP16] Félix Baschenis, Olivier Gauwin, Anca Muscholl, and Gabriele Puppis. Minimizing resources of sweeping and streaming string transducers. In *ICALP*, volume 55 of *LIPIcs*, pages 114:1–114:14. Schloss Dagstuhl - Leibniz-Zentrum für Informatik, 2016. Full version available at https://hal.archives-ouvertes.fr/hal-01274992.

[BGMP17] F. Baschenis, O. Gauwin, A. Muscholl, and G. Puppis. Untwisting two-way transducers in elementary time. In *Proceedings of the 32nd Annual ACM/IEEE Symposium on Logic in Computer Science (LICS)*. ACM, 2017.

[EH01] Joost Engelfriet and Hendrik Jan Hoogeboom. MSO definable string transductions and two-way finite-state transducers. *ACM Trans. Comput. Logic*, 2(2):216–254, 2001.

[FGRS13] Emmanuel Filiot, Olivier Gauwin, Pierre-Alain Reynier, and Frédéric Servais. From two-way to one-way finite state transducers. In *LICS*, pages 468–477. IEEE Computer Society, 2013.