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Decision Problems for Recognizable Languages of Infinite Pictures

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Altenbernd, Thomas and W\"ohrle have considered in [ATW02] acceptance of languages of infinite two-dimensional words (infinite pictures) by finite tiling systems, with the usual acceptance conditions, such as the B\"uchi and Muller ones, firstly used for infinite words. Many classical decision problems are studied in formal language theory and in automata theory and arise now naturally about recognizable languages of infinite pictures. We first review in this paper some recent results of [Fin09b] where we gave the exact degree of numerous undecidable problems for B\"uchi-recognizable languages of infinite pictures, which are actually located at the first or at the second level of the analytical hierarchy, and "highly undecidable". Then we prove here some more (high) undecidability results. We first show that it is Π_2^1-complete to determine whether a given B\"uchi-recognizable languages of infinite pictures is unambiguous. Then we investigate cardinality problems. Using recent results of [FL09], we prove that it is $D_2(\Sigma_1^1)$-complete to determine whether a given B\"uchi-recognizable language of infinite pictures is countably infinite, and that it is Σ_1^1-complete to determine whether a given B\"uchi-recognizable language of infinite pictures is uncountable. Next we consider complements of recognizable languages of infinite pictures. Using some results of Set Theory, we show that the cardinality of the complement of a B\"uchi-recognizable language of infinite pictures may depend on the model of the axiomatic system ZFC. We prove that the problem to determine whether the complement of a given B\"uchi-recognizable language of infinite pictures is countable (respectively, uncountable) is in the class $\Sigma_3^1 \setminus (\Pi_2^1 \cup \Sigma_2^1)$ (respectively, in the class $\Pi_3^1 \setminus (\Pi_2^1 \cup \Sigma_2^1)$).

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