(De-)Compositional Input/Output Conformance Testing based on Modal Interface Automata

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Formal approaches to model-based testing of concurrent systems define notions of *behavioral conformance* between a *specification* and a (black-box) *implementation (under test)*, both usually given as (variations of) labeled transitions systems (LTS). One of the most prominent conformance testing theories, initially introduced by Tretmans in [14], combines both views on formal conformance testing into an input/output conformance (**ioco**) relation on IOLTS. Although many formal properties of, and extensions to, **ioco** have been intensively investigated, **ioco** still suffers several essential weaknesses.

- **ioco** permits *underspecification* by means of (1) unspecified input behaviors and (2) non-deterministic input/output behaviors. But, concerning (1), **ioco** is limited to *positive* testing (i. e., unspecified inputs may be implemented arbitrarily) thus implicitly relying on optimistic environmental assumptions. Also supporting *negative* testing in a pessimistic setting, however, would require a distinction between *critical* and *uncritical* unintended input behaviors. Concerning (2), **ioco** requires the implementation to exhibit *at most* output behaviors permitted by the specification. In addition, the notion of *quiescence* (i. e., observable absence of any outputs) enforces implementations to show *at least one* specified output behavior (if any). Apart from that, no explicit distinction between *obligatory* and *allowed* output behaviors is expressible in IOLTS.
- **ioco** lacks a unified theory for input/output conformance testing in the face of concurrent behaviors being compatible with potential solutions for the aforementioned weaknesses.

As all these weaknesses mainly stem from the limited expressiveness of IOLTS as behavioral formalism, we propose *Modal Interface Automata with Input Refusals (IR-MIA)* as a new model for input/output conformance testing for both the specification and the implementation under test. IR-MIA adopt Modal Interface Automata (MIA) [3], which combine concepts of Interface Automata [5] (i. e., I/O automata permitting underspecified input behaviors) and (I/O-labeled) Modal Transitions Systems [6, 1, 12] (i. e., LTS with distinct mandatory and optional transition relations). In particular, we exploit enhanced versions of MIA supporting both optimistic and pessimistic environmental assumptions [9] and non-deterministic input/output behaviors [3]. For the latter, we have to re-interpret the universal state of MIA, simulating every possible behavior, as *failure state* to serve as target for those unintended, yet critical input behaviors to be *refused* by the implementation [11]. Modal refinement of IR-MIA therefore allows distinguishing between obligatory and allowed output behaviors, as well as between implicitly underspecified and explicitly forbidden input behaviors.

Based on previous work [8, 7], the resulting testing theory on IR-MIA unifies positive and negative conformance testing with optimistic and pessimistic environmental assumptions. Further, we have proven that the corresponding modal I/O conformance relation on IR-MIA, called **modal-irioco**, exhibits essential properties, especially with respect to concurrent systems testing.

- **modal-irioco** is preserved under modal refinement and constitutes a preorder under certain restrictions which can be obtained by a canonical input completion.
- **modal-irioco** is compositional with respect to parallel composition of IR-MIA with multi-cast and hiding [3].
- **modal-irioco** allows for decomposition of conformance testing, thus supporting environmental synthesis for testing in contexts [10]. To this end, we adapt the MIA quotient operator to IR-MIA, serving as the inverse to parallel composition.

For future work, we plan to address several open issues. First, we would like to enrich **modal-irioco** to handle real-time behavior. One interesting approach to this could be the adaption of notions of the several timed **ioco** relations [13] to **modal-irioco**. Second, we would like to be able to build test suites for **modal-irioco**. To solve this problem, we could adapt the idea of Beohar and Mousavi [2] who generate a test suite for **ioco** (based on Featured Transition Systems) by deriving an unfolding of a given IOLTS equipped with *pass*/*fail* predicates. Then, a system under test is conforming if *fail* is never reached. Third, and last, we would like to extend **modal-irioco** by multi-modalities [4]. Therewith, we are not only able to distinguish mandatory from optional behavior, but rather much more fine-grained refinement relations similar to **ioco** on FTS [2].

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