Perturbation & adaptation models for timed systems

Abstract

The main objective of this PhD is to consider perturbations in tied models, formal modeling of perturbation correction techniques, and the robustness of timed systems with perturbation and corrective mechanisms. This work can find an application in the context of collaboration with Alstom transport on the topic of metro systems modeling.

1 Topic

Robustness questions have met a huge interest in the last 15 years, since the seminal work of Puri [5]. The question addressed by Puri is the following: considering that perception of time in a real system is implemented using imperfect clocks, is there a clock precision that nevertheless allows faithful implementation of a system specified with and idealized representation of time, such as timed automata [1].

This question has been considered under several variants modeling time imprecision (guards enlargements or shrinking, clocks drift,...) [3], and generic solutions have been proposed to guarantee that some important properties of a system are robust to time imprecision [2].

Robustness questions can be considered in a more general setting, in which perturbations are part of the specification of the timed system. One can indeed consider that timed systems (such as train networks, production cells, etc...) have a nominal timed behavior, and that these idealized expected behaviors are perturbed according to a known perturbation model (that depicts the impact of failures, weather conditions, changes in pieces velocity due to friction,...). Moreover, in this setting, as perturbations are expected and part of the natural behavior of the system, these systems are equipped with corrective mechanisms, allowing to bring back a system close to a normal behavior. A typical example of such corrective mechanism can be seen in urban train networks, where delays are part of the normal behavior of the system (they are due to human behaviors, weather conditions or incidents) and can be absorbed, up to a certain limit, by application of regulation rules.

Modeling these systems is not as simple as it appears. Delays can somehow be handled by guards enlargements in timed automata [1] or timed Petri nets [4]. However, more contextual perturbations (velocity of pieces made with copper on a conveyor depends on the temperature,...) are not simple enlargements of guards. Timing modifications w.r.t a nominal behavior should be handled separately in a model, be part of a legal behavior, and call in some situations for changes in the behavior of the model starting from the identified perturbation. Another typical example is delay accumulation in systems, which is difficult to handle with guards in timed automata: trains are late, but they should continue their trip, even if transitions specify arrival and departures with some limit timing. In a similar way, it is difficult to integrate to existing discrete events models corrective techniques used to limit the impact of perturbations. In a metro, when a train is late, one can increase its speed on the next part of the network to catch up this delay. Brought back in a timed automaton context, this would mean dynamically changing the timed behavior of the model to allow earlier arrival, with values that depend on the observed delay. So far, such adaptative model have not yet been proposed.

The main topics considered in this PhD will be

- The design and study of formal models to represent timed systems with known ideal behavior subject to perturbations. The starting point for such model can be timed automata [1], or timed Petri nets [4].

- The design and study of formal models with perturbations and corrective techniques. A possible research direction is to extend timed automata to allow dynamic changes to transitions.

The second part of the PhD will consider robustness issues for some formal properties of perturbed and corrected models. The results of this PhD will find a natural application in the context of ongoing collaborations with Alstom Transport.

2 Supervision

This PhD will take place in the SUMO team. It will be supervised by Ocan Sankur and Loïc Hélouët.

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3 Competences

The PhD candidate must own a master degree or equivalent in computer science. This PhD topic does not require a priori competences, and will call for basic knowledge in formal modeling and mathematics : automata, set theory... However, a taste for formal techniques and prior exposure to theoretical computer science is preferable.

References

[1] Rajeev Alur and David Dill. A theory of timed automata. *In TCS*, 126(2):183–235, 1994.

[2] Patricia Bouyer, Nicolas Markey, and Ocan Sankur. Robust model-checking of timed automata via pumping in channel machines. In *Proc. of FORMATS*, volume 6919 of *LNCS*, pages 97–112. Springer, 2011.

[3] Martin De Wulf, Laurent Doyen, and Jean-François Raskin. Systematic implementation of real-time models. In *Proc. of Formal Methods*, volume 3582 of *LNCS*, pages 139–156. Springer, 2005.

[4] Philip M. Merlin. *A Study of the Recoverability of Computing Systems.* PhD thesis, University of California, Irvine, CA, USA, 1974.

[5] Anuj Puri. Dynamical properties of timed automata. *In DEDS*, 10(1-2):87–113, 2000.