STRUCTURED INTERACTIVE MUSICAL SCORES

MAURICIO TORO-BERMÚDEZ

1 Université de Bordeaux 1, Laboratoire Bordelais de Recherche en Informatique, Bâtiment A30. 351, cours de la Libération F-33405 Talence Cedex, France.

URL: http://www.labri.fr/perso/mtoro/

Abstract. Interactive Scores is a formalism for the design and performance of interactive scenarios that provides temporal relations (TRs) among the objects of the scenario. We can model TRs among objects in Time Stream Petri nets, but it is difficult to represent global constraints. This can be done explicitly in the Non-deterministic Timed Concurrent Constraint (ntcc) calculus. We want to formalize a heterogeneous system that controls in one subsystem the concurrent execution of the objects using ntcc, and audio and video processing in the other. We also plan to develop an automatic verifier for ntcc.

Introduction

Interactive Scores (IS) are currently used for the design and performance of Electroacoustic music [All08a] and live spectacles [Bal09] (e.g., interactive theater plays and interactive museums). Both applications are based on Petri nets [All08b]. The main purpose of IS is to provide temporal relations; for instance, precedence between two objects and relations between their durations. Recently, we extended IS to support conditional branching together with temporal relations [TB10]. It is now possible to represent loops and choices.

We can model temporal relations in Time Stream Petri nets (TSPN) [Sen95], but it is difficult to represent global constraints involving (possibly) all the objects of the scenario. Instead, in Concurrent Constraint Programming (ccp) [Sar92] there are agents that reason about partial information contained in a constraint store; thus, global constraints are inherent in ccp. However, there is not discrete time in ccp, which makes it difficult to represent reactive systems.

There are some IS models based on extensions of ccp with discrete time. An example is the Non-deterministic Timed Concurrent Constraint (ntcc) model of IS [Nie02, All06]. Ntcc is an extension of ccp for non-determinism, asynchrony and discrete time.

Ntcc belongs to a family of formalisms called process calculi. Process calculi has been applied to the modeling of interactive multimedia systems [TOR16b, TOR16d, Tor16a, TOR15c, All11, Tor14a, Tor09c, Ola11, Tor10a, Tor09a, Tor15a, Ara09, Tor12b, Tor09b, Tor10b, Tor10c, Tor08], spatially-explicit ecological systems [Tor16c, Phi13a, Tor14b, Phi13b, Tor15b], data Structures [PF16, Mor17, Res17].

1998 ACM Subject Classification: D. Software, D.1 Programming techniques, D.1.3 Concurrent programming, D.1.5 Logic programming.

Key words and phrases: ntcc, ccp, interactive scores, temporal relations, faust, ntccrt, heterogeneous systems, automatic verification.
In the declarative view, ntcc processes can be interpreted as linear temporal logic formulae [Pnu77]. The ntcc model includes an inference system in this logic to verify properties of ntcc models. This inference procedure was proved to be of exponential time complexity. Nevertheless, we believe practical automatic verification could be envisioned for useful subsets of ntcc via model checking (see [Fal06]). At present, there is no such automatic verifier for ntcc.

Automated verification for ntcc will provide information about the correctness of the system to computer scientists, and will provide important properties about the scenario to its designers and users; for instance, reachability and liveness. We plan to augment ntcc models of IS with these features.

1. Current and future work

Functional AUdio STream (Faust) [Orl04] is a programming language for signal processing with formal semantics and Ntccrt [Tor09c] is a real-time capable interpreter for ntcc. We implemented a signal processing prototype where Faust and Ntccrt interact together. In the future, we want to define formal semantics to describe a heterogeneous system that includes three subsystems: (i) one based on ntcc to control discrete events from the user and to synchronize the objects of the scenario, (ii) another one based on Faust to process audio and video, and finally (iii) one in charge to load and play audio and video files.

At the time of this writing, there are no formal semantics of a heterogeneous system that synchronizes concurrent objects, handles global constraints, and controls audio and video streams. Modeling this kind of systems will be useful in other domains such as machine musical improvisation [Ass04] and music video games. An advantage over the existing implementations of these systems will be verification.

In the proof system of ntcc, we can prove properties like “10 time units (TUs) after the event $e_A$, during the next 4 TUs, the stream $B$ is the result of applying a gain filter to the stream $A$”. However, real-time audio processing cannot be implemented in Ntccrt because it requires to simulate 44100 TUs per second to process a 44.1 kHz sound. If we replace some ntcc processes by Faust plugins, we can execute such system efficiently, but we cannot verify that the properties of the system hold.

There are two open issues: (i) how to prove that a Faust plugin that replaces a ntcc process respect the temporal properties proved for the process, and (ii) whether an implementation of Interactive Scores in Ntccrt can be as efficient as the existing Petri nets implementation, or as one using synchronous languages such as Signal [Gau87], although the performance results from Ntccrt are promising.

Acknowledgement

I wish to acknowledge fruitful discussions with my supervisors Myriam Desainte-Catherine and Camilo Rueda. I also want to thank them for helping me writing this article and for guiding my current research.

1We ran a prototype of a score with conditional branching in Ntccrt. The score contains 500 temporal objects. The average duration of each time-unit was 30 ms, which is compatible with real-time interaction.
References

[All06] Antoine Allombert, Gérard Assayag, M. Desainte-Catherine, and Camilo Rueda. Concurrent constraint models for interactive scores. In Proc. of SMC ’06. 2006. URL http://www.labri.fr/publications/is/2006/AADR06

[All08a] Antoine Allombert, G. Assayag, and M. Desainte-Catherine. Iscore: a system for writing interaction. In Proc. of DIMEA ’08, pp. 360–367. ACM, New York, NY, USA, 2008.

[All08b] Antoine Allombert, Myriam Desainte-Catherine, J. Larralde, and Gérard Assayag. A system of interactive scores based on qualitative and quantitative temporal constraints. In Proc. of Artech 2008. 2008.

[All11] Antoine Allombert, Myriam Desainte-Catherine, and Mauricio Toro. Modeling temporal constrains for a system of interactive score. In Gérard Assayag and Charlotte Truchet (eds.), Constraint Programming in Music, chap. 1, pp. 1–23. Wiley, 2011.

[Ara09] Jesús Aranda, Gérard Assayag, Carlos Olarte, Jorge A. Pérez, Camilo Rueda, Mauricio Toro, and Frank D. Valencia. An overview of FORCES: an INRIA project on declarative formalisms for emergent systems. In Patricia M. Hill and David Scott Warren (eds.), Logic Programming, 25th International Conference, ICLP 2009, Pasadena, CA, USA, July 14-17, 2009. Proceedings, Lecture Notes in Computer Science, vol. 5649, pp. 509–513. Springer, 2009. doi:10.1007/978-3-642-02846-5_44. URL http://dx.doi.org/10.1007/978-3-642-02846-5_44

[Ass04] G. Assayag and Sholomo Dubnov. Using factor oracles for machine improvisation. Soft Comput., 8(9):604–610, 2004. doi:http://dx.doi.org/10.1007/s00500-004-0385-4. URL http://mediatheque.ircam.fr/articles/textes/Assayag04a/

[Bal09] P. Baltazar, A. Allombert, R. Marczak, J.M. Couturier, M. Roy, A. Sèdes, and M. Desainte-Catherine. Virage : Une reflexion pluridisciplinaire autour du temps dans la création numérique. In in Proc. of JIM. 2009.

[Fal06] Moreno Falaschi and Alicia Villanueva. Automatic verification of timed concurrent constraint programs. Theory Pract. Log. Program, 6(4):265–300, 2006.

[Gau87] Thierry Gautier, Paul Le Guernic, and Léoc Besnard. Signal: A declarative language for synchronous programming of real-time systems. In Proc. of FPCA ’87. 1987.

[Mor17] Juan David Arcila Moreno, Santiago Passos, and Mauricio Toro. On-line assembling mitochondrial DNA from de novo transcriptome. CoRR, abs/1706.02828, 2017. URL http://arxiv.org/abs/1706.02828

[Nie02] M. Nielsen, C. Palamidessi, and F. Valencia. Temporal concurrent constraint programming: Denotation, logic and applications. Nordic Journal of Comp., 1, 2002. URL citeseer.ist.psu.edu/article/nieelsen02temporal.html

[Ola11] Carlos Olarte, Camilo Rueda, Gerardo Sarria, Mauricio Toro, and Frank Valencia. Concurrent Constraints Models of Music Interaction. In Gérard Assayag and Charlotte Truchet (eds.), Constraint Programming in Music, chap. 6, pp. 133–153. Wiley, Hoboken, NJ, USA., 2011.

[Orl04] Y. Orlarey, D. Fober, and S. Letz. Syntactical and semantical aspects of faust. Soft Comput., 8(9):623–632, 2004. doi:http://dx.doi.org/10.1007/s00500-004-0388-1. URL http://portal.acm.org/citation.cfm?id=1028287

[PF16] C. Patiño-Forero, M. Agudelo-Toro, and M. Toro. Planning system for deliveries in Medellín. ArXiv e-prints, 2016.

[Phi13a] Anna Philippou and Mauricio Toro. Process Ordering in a Process Calculus for Spatially-Explicit Ecological Models. In Proceedings of MOKMASD’13, LNCS 8368, pp. 345–361. Springer, 2013.

[Phi13b] Anna Philippou, Mauricio Toro, and Margarita Antonaki. Simulation and Verification for a Process Calculus for Spatially-Explicit Ecological Models. Scientific Annals of Computer Science, 23(1):119–167, 2013. URL http://www.cs.ucy.ac.cy/~annap/ptm2013.pdf

[Pnu77] A. Pnueli. The temporal logic of programs. In Proc. of the 18th IEEE Symposium on the Foundations of Computer Science (FOCS-77), pages 46-57. IEEE, IEEE Computer Society Press, 1977. 1977.

[Res17] Juan Manuel Ciro Restrepo, Andrés Felipe Zapata Palacio, and Mauricio Toro. Assembling sequences of DNA using an on-line algorithm based on debruijn graphs. CoRR, abs/1705.05105,
[Sar92] Vijay A. Saraswat. Concurrent Constraint Programming. MIT Press, 1992.

[Sen95] Patrick Senac, Pierre de Saqui-Sannes, and Roberto Willrich. Hierarchical time stream petri net: A model for hypermedia systems. In Proc. of the 16th International Conference on Application and Theory of Petri Nets, pp. 451–470. Springer-Verlag, London, UK, 1995.

[TB10] Mauricio Toro-B., Myriam Desainte-Catherine, and P. Baltazar. A model for interactive scores with temporal constraints and conditional branching. In Proc. of Journées d’informatique musicale (JIM) ’10 (to appear). 2010.

[Tor08] Mauricio Toro. Exploring the possibilities and limitations of concurrent programming for multimedia interaction and graphical representations to solve musical CSP’s. Tech. Rep. 2008-3, Ircam, Paris.(FRANCE), 2008.

[Tor09a] Mauricio Toro. Probabilistic Extension to the Factor Oracle Model for Music Improvisation. Master’s thesis, Pontificia Universidad Javeriana Cali, Colombia, 2009.

[Tor09b] Mauricio Toro. Towards a correct and efficient implementation of simulation and verification tools for probabilistic nttc. Tech. rep., Pontificia Universidad Javeriana, 2009.

[Tor09c] Mauricio Toro, Carlos Agón, Gérard Assayag, and Camilo Rueda. Ntccrt: A concurrent constraint framework for real-time interaction. In Proc. of ICMC ’09, Montreal, Canada, 2009.

[Tor10a] Mauricio Toro. Structured interactive musical scores. In Manuel V. Hermenegildo and Torsten Schaub (eds.), Technical Communications of the 26th International Conference on Logic Programming, ICLP 2010, July 16-19, 2010, Edinburgh, Scotland, UK, LIPICS, vol. 7, pp. 300–302. Schloss Dagstuhl - Leibniz-Zentrum fuer Informatik, 2010. doi:10.4230/LIPICS.ICALP.2010.300.

[Tor10b] Mauricio Toro and Myriam Desainte-Catherine. Concurrent constraint conditional branching interactive scores. In Proc. of SMC ’10. Barcelona, Spain, 2010.

[Tor10c] Mauricio Toro, Myriam Desainte-Catherine, and P. Baltazar. A model for interactive scores with temporal constraints and conditional branching. In Proc. of Journées d’Informatique Musicale (JIM) ’10. 2010.

[Tor12a] Mauricio Toro. Structured Interactive Scores: From a simple structural description of a multimedia scenario to a real-time capable implementation with formal semantics. Ph.D. thesis, Univeristé de Bordeaux 1, France, 2012.

[Tor12b] Mauricio Toro, Myriam Desainte-Catherine, and Julien Castet. An extension of interactive scores for multimedia scenarios with temporal relations for micro and macro controls. In Proc. of Sound and Music Computing (SMC) ’12, Copenhagen, Denmark, 2012.

[Tor14a] Mauricio Toro, Myriam Desainte-Catherine, and Camilo Rueda. Formal semantics for interactive music scores: a framework to design, specify properties and execute interactive scenarios. Journal of Mathematics and Music, 8(1):93–112, 2014. doi:10.1080/17459737.2013.870610.

[Tor14b] Mauricio Toro, Anna Philippou, Christina Kassara, and Spyros Sfenthourakis. Synchronous parallel composition in a process calculus for ecological models. In Gabriel Ciobanu and Dominique Méry (eds.), Proceedings of the 11th International Colloquium on Theoretical Aspects of Computing - ICTAC 2014, Bucharest, Romania, September 17-19, Lecture Notes in Computer Science, vol. 8687, pp. 424–441. Springer, 2014. doi:10.1007/978-3-319-10882-7 25.

[Tor15a] Mauricio Toro. Structured interactive music scores. CoRR, abs/1508.05559, 2015.

[Tor15b] Mauricio Toro, Anna Philippou, Sair Arboleda, Carlos Vélez, and María Puerta. Meanfield semantics for a Process Calculus for Spatially-Explicit Ecological Models. Tech. rep., Department of Informatics and Systems, Universidad Eafit, 2015. Available at http://blogs.eafit.edu.co/giditic-software/2015/10/01/mean-field/
[Tor16a] M. Toro. Probabilistic Extension to the Concurrent Constraint Factor Oracle Model for Music Improvisation. *ArXiv e-prints*, 2016.

[TOR16b] MAURICIO TORO, MYRIAM DESAINTE-CATHERINE, and JULIEN CASTET. An extension of interactive scores for multimedia scenarios with temporal relations for micro and macro controls. *European Journal of Scientific Research*, 137(4):396–409, 2016.

[Tor16c] Mauricio Toro, Anna Philippou, Sair Arboleda, María Puerta, and Carlos M. Vélez S. Mean-field semantics for a process calculus for spatially-explicit ecological models. In César A. Muñoz and Jorge A. Pérez (eds.), Proceedings of the Eleventh International Workshop on *Developments in Computational Models*, Cali, Colombia, October 28, 2015, *Electronic Proceedings in Theoretical Computer Science*, vol. 204, pp. 79–94. Open Publishing Association, 2016. doi:10.4204/EPTCS.204.7.

[TOR16d] MAURICIO TORO, CAMILO RUEDA, CARLOS AGÓN, and GÉRARD ASSAYAG. Gelisp: A framework to represent musical constraint satisfaction problems and search strategies. *Journal of Theoretical & Applied Information Technology*, 86(2), 2016.