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► **To cite this version:**

Julien Alexandre Dit Sandretto, Alexandre Chapoutot, Olivier Mullier. Survey of what DynIbex can do for you. 2018. hal-01927784

HAL Id: hal-01927784

<https://hal.science/hal-01927784>

Preprint submitted on 20 Nov 2018

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Survey of what DynIbex can do for you

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November 16, 2018

Abstract

This paper aims at gathering the capabilities of the tool DynIbex, in term of differential equations that can be handled, the facilities for constraint programming with differential equations, and the applications already done by the help of this tool. It collects all of our contributions produced on, or by the help of, DynIbex.

Keywords: validated numerical integration; Runge-Kutta methods; control synthesis; appropriate design; viability kernel; motion planning; model predictive control; hybrid systems.

1 Capabilities of DynIbex

The main goal of DynIbex is to offer a set of validated numerical integration methods, based on Runge-Kutta schemes, to solve initial value problem (IVP) of ordinary differential equations (ODE) and for differential algebraic equations (DAE) in Hessenberg index 1 form. For this purpose, the Runge-Kutta schemes, explicit and implicit, are validated by a guaranteed bounding of their local truncation errors [17, 7]. With these validated schemes, DynIbex is able to solve initial value problems in a guaranteed way [2]. A specific method is also available to solve differential algebraic equations [3, 8]. In order to reduce the complexity on the local truncation computation, and hence to increase the size of the problems being handled, a method based on automatic differentiation (a.k.a. algorithmic differentiation) is used for problems of dimension greater than 3 [23, 24]. An approach based on contractor programming can be exploited to improve some algorithms. This approach proposes contraction, propagation and bisection capabilities on a computed simulation of ODE [4]. By combining DynIbex with geometrical techniques, it is possible to compute the reachability of IVPs whose initial value is given in term of polytopes [15].

2 Verification of cyber-physical systems

Some functionalities of DynIbex are specifically developped to study, verify or validate dynamical systems and cyber-physical systems. These functionalities exploit the constraint programming formalism [5, 6, 12].

3 Applications done with DynIbex

DynIbex can be used for the synthesizing of controller parameters such as proportional-integral controller [9]. It is also a useful tool for the appropriate design of robots [14].

In term of invariant computation, DynIbex is used for the characterization of the viability kernel [22, 21, 20].

A particular class of dynamical systems that are the switched systems can be considered in DynIbex. Indeed, the control synthesis of this kind of systems can be performed with this tool [18, 19].

The verification of robotic behavior can be done with DynIbex. It allows to build a robust motion planner based on Rapidly-exploring random tree method [10, 11].

Another approach for motion planning, this time based on sliding horizon uses DynIbex [16].

A reliable model-predictive control for nonlinear dynamical systems using DynIbex is proposed in [1].

In term of optimal control, the synthesis of optimal switching instants are performed for the control of hybrid systems in [13].

References

- [1] Julien Alexandre dit Sandretto. Reliable NonLinear Model-Predictive Control via Validated Simulation. In *American Control Conference (ACC)*, Milwaukee, USA, June 2018.
- [2] Julien Alexandre dit Sandretto. Validated Runge-Kutta Methods for Initial Value Problems. In *ANODE*, Auckland, New Zealand, February 2018.
- [3] Julien Alexandre dit Sandretto and Alexandre Chapoutot. Validated Simulation of Differential Algebraic Equations. In *Small Workshop on Interval Methods*, Prague, Czech Republic, June 2015.
- [4] Julien Alexandre dit Sandretto and Alexandre Chapoutot. Contraction, propagation and bisection on a validated simulation of ODE. In *Summer Workshop on Interval Methods*, Lyon, France, June 2016.
- [5] Julien Alexandre dit Sandretto and Alexandre Chapoutot. DynBEX: a Differential Constraint Library for Studying Dynamical Systems. In *Conference on Hybrid Systems: Computation and Control (HSCC 2016)*, Vienne, Austria, April 2016.
- [6] Julien Alexandre dit Sandretto and Alexandre Chapoutot. DynIBEX: une boîte à outils pour la vérification des systèmes cyber-physiques. In *Approches Formelles dans l'Assistance au Développement de Logiciels*, Besançon, France, June 2016.
- [7] Julien Alexandre dit Sandretto and Alexandre Chapoutot. Validated Explicit and Implicit Runge-Kutta Methods. *Reliable Computing electronic edition*, 22, July 2016.

- [8] Julien Alexandre dit Sandretto and Alexandre Chapoutot. Validated Simulation of Differential Algebraic Equations with Runge-Kutta Methods. *Reliable Computing electronic edition*, 22, July 2016.
- [9] Julien Alexandre dit Sandretto, Alexandre Chapoutot, and Olivier Mullier. Tuning PI controller in non-linear uncertain closed-loop systems with interval analysis. In *Workshop on Synthesis of Complex Parameters*, Londres, United Kingdom, April 2015.
- [10] Julien Alexandre dit Sandretto, Alexandre Chapoutot, and Olivier Mullier. Formal Verification of Robotic Behaviors in Presence of Bounded Uncertainties. In *First IEEE International Conference on Robotic Computing*, Taichung, Taiwan, April 2017.
- [11] Julien Alexandre dit Sandretto, Alexandre Chapoutot, and Olivier Mullier. Formal Verification of Robotic Behaviors in Presence of Bounded Uncertainties. *Journal of Software Engineering for Robotics*, 8(1):78–88, 2017.
- [12] Julien Alexandre dit Sandretto, Alexandre Chapoutot, and Olivier Mullier. Constraint-based framework for reasoning with differential equations. *Cyber-Physical Systems Security*, 2018.
- [13] Julien Alexandre dit Sandretto, Olivier Mullier, and Alexandre Chapoutot. Optimal Switching Instants for the Control of Hybrid Systems. In *Summer Workshop on Interval Methods*, Rostock, Germany, July 2018.
- [14] Julien Alexandre dit Sandretto, Douglas Piccani de Souza, and Alexandre Chapoutot. Appropriate Design Guided by Simulation: An Hovercraft Application. In *Workshop on Model-Driven Robot Software Engineering*, Leipzig, Germany, July 2016.
- [15] Julien Alexandre dit Sandretto and Jian Wan. Reachability analysis of nonlinear odes using polytopic based validated runge-kutta. In Igor Potapov and Pierre-Alain Reynier, editors, *Reachability Problems*, pages 1–14. Springer International Publishing, 2018.
- [16] Elliot Brendel, Julien Alexandre dit Sandretto, and Alexandre Chapoutot. Robust Motion Planning Based on Sliding Horizon and Validated Simulation. In *10th Summer Workshop on Interval Methods, and 3rd International Symposium on Set Membership - Applications, Reliability and Theory*, Manchester, United Kingdom, June 2017.
- [17] Alexandre Chapoutot, Julien Alexandre dit Sandretto, and Olivier Mullier. Validated Explicit and Implicit Runge-Kutta Methods. In *Small Workshop on Interval Methods*, Prague, Czech Republic, June 2015.
- [18] Adrien Le Coent, Julien Alexandre dit Sandretto, Alexandre Chapoutot, and Laurent Fribourg. Control of Nonlinear Switched Systems Based on Validated Simulation. In *International Workshop on Symbolic and Numerical Methods for Reachability Analysis (SNR'16)*, Vienne, Austria, April 2016.

- [19] Adrien Le Coënt, Julien Alexandre dit Sandretto, Alexandre Chapoutot, and Laurent Fribourg. An Improved Algorithm for the Control Synthesis of Nonlinear Sampled Switched Systems. *Formal Methods in System Design*, November 2017.
- [20] Benjamin Martin and Olivier Mullier. Improving validated computation of viability kernels. In *Proceedings of the 21st International Conference on Hybrid Systems: Computation and Control (part of CPS Week)*, pages 227–236. ACM, 2018.
- [21] Dominique Monnet, Luc Jaulin, Jordan Ninin, Alexandre Chapoutot, and Julien Alexandre dit Sandretto. Inner and Outer Computation of the Viability Kernel based on Interval Analysis. In *International Symposium on Set Membership - Applications, Reliability and Theory*, Manchester, United Kingdom, September 2015.
- [22] Dominique Monnet, Luc Jaulin, Jordan Ninin, Alexandre Chapoutot, and Julien Alexandre dit Sandretto. Viability kernel computation based on interval methods. In *Small Workshop on Interval Methods*, Prague, Czech Republic, June 2015.
- [23] Olivier Mullier, Alexandre Chapoutot, and Julien Alexandre dit Sandretto. Validated Computation of the Local Truncation Error of Runge-Kutta Methods with Automatic Differentiation. International Conference on Algorithmic Differentiation, September 2016. Poster.
- [24] Olivier Mullier, Alexandre Chapoutot, and Julien Alexandre dit Sandretto. Validated Computation of the Local Truncation Error of Runge-Kutta Methods with Automatic Differentiation. *Optimization Methods and Software*, 2018.