IEEE Control Systems Society
Technical Committee on Discrete Event Systems

Newsletter **June 2024**

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https://ieeecss.org/tc/discrete-event-systems/newsletters

Editorial

You are welcome to submit new items to the newsletter (topics including schools, workshops, sessions, conferences, journals, books, software, positions). Also please encourage relevant colleagues and students to subscribe to this newsletter.

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Contents

1 Selections of Journal Publications

Contributed by: Xiang Yin (yinxiang@sjtu.edu.cn)

1.1. Discrete Event Dynamic Systems Theory and Applications

Volume: 34, Issue: 2, June 2024

- **Simulations and bisimulations for max-plus automata**
  Authors: Miroslav Ćirić ; Ivana Micić ; Jelena Matejić ; Aleksandar Stamenković
  Abstract: Two types of simulations and four types of bisimulations for weighted finite automata over the complete max-plus semiring we define as solutions of particular systems of matrix inequations. We provide a procedure that either decides that there is a simulation or bisimulation of a given type between two automata, and outputs the greatest one, or decides that no simulation or bisimulation of that type exists. The procedure is iterative and does not have to end in a finite number of steps. Certain conditions under which this procedure must terminate in a finite number of steps are described in a slightly more general context in Stamenković et al. (Discrete Event Dynamic Systems, 32:1–25, 2022). We also propose a modification of this procedure which, in case there is no simulation or bisimulation of a given type between two max-plus automata, detects this in finitely many steps and faster than the original procedure. In the same case, that modification also finds a natural number such that containment or equivalence is valid for all input words of length less than that number. For max-plus automata with non-negative weights, we point out the differences that occur when the above mentioned procedure is applied over the complete max-plus semiring, and when it is applied over its non-negative part with minus infinity added.
- **Triangulation of diagonally dominant min-plus matrices**
  Authors: Yuki Nishida ; Sennosuke Watanabe ; Yoshihide Watanabe
  Abstract: The min-plus algebra is a commutative semiring with two operations: addition $a \oplus b := \min(a, b)$ and multiplication $a \otimes b := a+b$. In this paper, we discuss a min-plus algebraic counterpart of matrix diagonalization in conventional linear algebra. Due to the absence of subtraction in the min-plus algebra, few matrices admit such a canonical form. Instead, we consider triangulation of min-plus matrices in terms of algebraic eigenvectors, which is an extended concept of usual eigenvectors. We deal with two types of min-plus matrices: strongly diagonally dominant (SDD) and nearly diagonally dominant (NDD) matrices. For an SDD matrix, the roots of the characteristic polynomial coincide with its diagonal entries. On the other hand, for an NDD matrix, the roots except for the maximum one appear in diagonal entries. We show that SDD matrices admit upper triangulation whose diagonal entries are algebraic eigenvalues, while NDD matrices admit block upper triangulation. We exhibit applications of triangulation of min-plus matrices to traffic flow models.
- **An algebraic control method to guarantee generalized marking constraints for partially observable timed event graphs**
  Authors: Jihene Rajah ; Said Amari ; Maher Barkallah ; Mohamed Haddar
  Abstract: This work deals with the control problem of Discrete Event Systems (DESs) modelled by Timed Event Graphs (TEGs) and subject to Generalized Marking Constraints (GMCs). The aim of this paper is to propose an algebraic methodology for the determination of control laws in the form of state feedback, guaranteeing the satisfaction of marking specifications expressed by weighted inequalities in the Min-Plus algebra. The resultant controller can be represented by marked and timed control places, connected to the initial TEG model. The role of the established feedback is to limit the number of tokens in weighted paths for partially observable TEGs. In order to illustrate and show the interest of these current studies, we applied the suggested control method to a machine of filling bottles with liquid.
- **Offline analysis of the relaxed upper boundedness for online estimation ofoptimal event sequences in Partially Observable Petri Nets**
  Authors: P. Declerck
  Abstract: The aim of this paper is the analysis of the property of the relaxed structurally boundedness of the unobservable subnet of the Petri net which brings a condition guaranteeing the finitude

of all possible sequence lengths in the context of an on-line estimation in Partially Observable Petri Nets relevant to a sliding horizon or a receding horizon starting from the initial marking. Based on specific invariants defined over the real numbers, the approach focuses on an offline structural analysis, that is, the determination of the parts of the unobservable subnet where an online estimation for any criterion can be made. The decomposition-composition technique is based on a block triangular form obtained with any technique. The composition of the substructures leads to a propagation of the relaxed structurally boundedness property through the structure. The study of a large-scale manufacturing system shows that the direct treatment of the large system system can be avoided and that the triangular form brings a sequential treatment allowing a computation based on smaller systems independently of the resolution of the complete system.

- **MGF-based SNC for stationary independent Markovian processes with localized application of martingales**
  Authors: Anne Bouillard
  Abstract: Stochastic Network Calculus is a probabilistic method to compute performance bounds in networks, such as end-to-end delays. It relies on the analysis of stochastic processes using formalism of (Deterministic) Network Calculus. However, unlike the deterministic theory, the computed bounds are usually very loose compared to the simulation. This is mainly due to the intensive use of the Boole's inequality. On the other hand, analyses based on martingales can achieve tight bounds, but until now, they have not been applied to sequences of servers. In this paper, we improve the accuracy of Stochastic Network Calculus by combining this martingale analysis with a recent Stochastic Network Calculus results based on the Pay-Multiplexing-Only-Once property, well-known from the Deterministic Network calculus. We exhibit a non-trivial class of networks that can benefit from this analysis and compare our bounds with simulation.

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1.2. IEEE Transactions on Automatic Control

Volume: 69, Issue: 6, June 2024

- **Supervisory Control of Modular Discrete-Event Systems Under Partial Observation: Normality**
  Authors: Jan Komenda ; Tomáš Masopust
  Abstract: Complex systems are often composed of many small communicating components called modules. We investigate the synthesis of supervisory controllers for modular systems under partial observation that, as the closed-loop system, realize the supremal normal sublanguage of the specification. Such controllers are called maximally permissive normal supervisors. The challenge in modular systems is to find conditions under which the global nonblocking and maximally permissive normal supervisor can be achieved locally as the parallel composition of local normal supervisors. We show that a structural concept of hierarchical supervisory control called modified observation consistency (MOC) is such a condition. However, the algorithmic verification of MOC is an open problem, and therefore it is necessary to find easily verifiable conditions that ensure MOC. We show that the condition that all shared events are observable is such a condition. Considering specifications, we examine both local specifications, where each module has its own specification, and global specifications. Combining our results for normality with the existing results for controllability yields the local synthesis of the nonblocking and maximally permissive controllable and normal supervisor. Finally, we illustrate the results on an industrial case study of the patient table of an MRI scanner.

- **Strong Consistency and Rate of Convergence of Switched Least Squares System Identification for Autonomous Markov Jump Linear Systems**
  Authors: Borna Sayedana ; Mohammad Afshari ; Peter E. Caines ; Aditya Mahajan
  Abstract: In this article, we investigate the problem of system identification for autonomous Markov jump linear systems (MJS) with complete state observations. We propose switched least squares method for identification of MJS, show that this method is strongly consistent, and derive data-dependent and data-independent rates of convergence. In particular, our data-independent rate of convergence shows that, almost surely, the system identification error is $\mathcal{O}(\sqrt{\log(T)/T})$

where T is the time horizon. These results show that the switched least squares method for MJS has the same rate of convergence as the least squares method for autonomous linear systems. We derive our results by imposing a general stability assumption on the model called stability in the average sense. We show that stability in the average sense is a weaker form of stability compared with the stability assumptions commonly imposed in the literature. We present numerical examples to illustrate the performance of the proposed method.

- **A Hitting Time Analysis for Stochastic Time-Varying Functions With Applications to Adversarial Attacks on Computation of Markov Decision Processes**
  Authors: Ali Yekkehkhany ; Han Feng ; Donghao Ying ; Javad Lavaei
  Abstract: Stochastic time-varying optimization is an integral part of learning in which the shape of the function changes over time in a nondeterministic manner. This article considers multiple models of stochastic time variation and analyzes the corresponding notion of hitting time for each model, i.e., the period after which optimizing the stochastic time-varying function reveals informative statistics on the optimization of the target function. The studied models of time variation are motivated by adversarial attacks on the computation of value iteration in Markov decision processes. In this application, the hitting time quantifies the extent that the computation is robust to adversarial disturbances. We develop upper bounds on the hitting time by analyzing the contraction–expansion transformation appearing in the time-variation models. We prove that the hitting time of the value function in the value iteration with a probabilistic contraction–expansion transformation is logarithmic in terms of the inverse of a desired precision. In addition, the hitting time is analyzed for optimization of unknown continuous or discrete time-varying functions whose noisy evaluations are revealed over time. The upper bound for a continuous function is super-quadratic (but subcubic) in terms of the inverse of a desired precision and the upper bound for a discrete function is logarithmic in terms of the cardinality of the function domain. Improved bounds for convex functions are obtained and we show that such functions are learned faster than nonconvex functions. Finally, we study a time-varying linear model with additive noise, where hitting time is bounded with the notion of shape dominance.

- **On Minimum Realization of Boolean Control Networks**
  Authors: Yongyuan Yu ; Caixia Wang ; Jun-e Feng ; Ge Chen
  Abstract: This article investigates the relationship between realization and observability of Boolean control networks (BCNs) and gives some invariants under minimum realization (MR), such as, decoupling, invertibility, etc. It is proved that the MR of a BCN exists uniquely up to coordinate transformations and a BCN is an MR of itself if and only if it is weakly observable. Based on these, the MR of a given BCN can be constructed. Moreover, the observability decomposition of BCNs is discussed and an equivalent condition is obtained to determine the decomposability, which guarantees the existence and uniqueness of the regular MR (RMR) that is a special type of MR. Then, the RMR of the given BCN can be obtained. Finally, an example is given to show the effectiveness of the obtained results.

- **Lossless State Compression of Boolean Control Networks**
  Authors: Bowen Li ; Jianquan Lu ; Wenying Xu ; Jie Zhong
  Abstract: In this article, the problem of lossless state compression of Boolean control networks is first investigated. Two compression protocols are introduced, based on which an inequality relation between the smallest compressed state walk and a source state walk is established to search all the eligible compressed state walks. Then, by defining indistinguishable trajectories and utilizing the semitensor product approach, some matrix-based conditions for the solvability of lossless state compression are derived. In order to reduce constraints, the finite-state automaton method is proposed to obtain more applicable solvability conditions. Furthermore, in order to improve the compression ratio, one algorithm is given to construct the minimal recoverable compressed state walk. Finally, some examples are given to illustrate the efficiency of the derived results, in which the compression ratio can reach 33.3%.

- **Finite-Time Stabilization of Uncertain Markovian Jump Systems: An Adaptive Gain-Scheduling Control Method**
  Authors: Zhiru Cao ; Yugang Niu ; Chen Peng

Abstract: This article addresses the stochastic finite-time stabilization problem for a class of Markovian jump systems with polytopic uncertainties. First, an adaptive gain-scheduling-based control design method is well proposed. Compared with the traditional common/parameter-independent control method, the polytopic structure characteristic is well used via approximating uncertain parameters in controller design, which might reduce the conservatism and improve the flexibility of control design. Second, the controller gains and the transition rate matrix are codesigned to ensure the stochastic finite-time stability of the closed-loop system. Furthermore, an optimization problem is also established by minimizing the constrained upper bound of the system state to achieve the optimal closed-loop performance. Finally, two numerical examples are adopted to illustrate the effectiveness of the proposed method.

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1.3. Automatica

Volume: 164, June 2024

- **Liveness and deadlock-freeness verification and enforcement in bounded Petri nets using basis reachability graphs**
  Authors: Chao Gu ; Ziyue Ma ; Zhiwu Li
  Abstract: This paper studies the verification and enforcement of deadlock-freeness and liveness in partially controllable Petri nets. First, we introduce a particular type of basis reachability graphs called conflict-free-control-explicit basis reachability graphs (CFCE-BRGs), in which the firings of all structurally conflicting transitions and all controllable ones are explicitly encoded. We propose two sufficient and necessary conditions for verifying deadlock-freeness and liveness of a Petri net; both can be verified by inspecting a CFCE-BRG using graph theory. Moreover, we develop two maximally permissive deadlock-freeness and liveness enforcing supervisors based on the trimming of CFCE-BRGs. The developed approaches are applicable to arbitrary bounded Petri nets, without an exhaustive reachability space enumeration.
- **On the verification of detectability for timed discrete event systems**
  Authors: Weijie Dong ; Kuize Zhang ; Shaoyuan Li ; Xiang Yin
  Abstract: In this paper, we investigate the problem of state estimation and detection in the context of timed discrete-event systems. Specifically, we study the verification of detectability, a fundamental state estimation property for dynamic systems. Existing works on this topic mainly focus on untimed DESs. In some applications, however, real-time information is critical for the purpose of system analysis. To this end, in this paper, we investigate the verification of detectability for timed DESs modeled by partially-observed timed automata. Three notions of detectability, strong detectability, weak detectability and delayed detectability, are studied in a dense-time setting, which characterizes detectability by time elapsing rather than event updating steps. We show that verifying strong detectability and delayed detectability for partially-observed timed automata is decidable by providing verifiable necessary and sufficient conditions. Furthermore, we show that weak detectability is undecidable in the timed setting by reducing the language universality problem for timed automata to the verification problem of weak detectability. Our results extend the detectability analysis of DESs from the untimed setting to a timed setting.
- **Optimal supervisory control of discrete event systems for cyclic tasks**
  Authors: Peng Lv ; Zhangcong Xu ; Yiding Ji ; Shaoyuan Li ; Xiang Yin
  Abstract: In this paper, we investigate the problem of optimal supervisory control for cyclic tasks in the context of discrete-event systems (DES). We consider the completion of each single task as the visit of a marked state, and overall control objective is to complete tasks cyclically in the sense that marked states are visited infinitely often. Following the standard optimal supervisory control framework, two types of costs, disable cost and occurrence cost, are considered. However, instead of considering the standard accumulated total cost or the average cost per event, we consider the measure for the control performance using the average cost per task. We show that such an optimality measure is more suitable for tasks that need to be completed cyclically. Our goal is to design a live and non-blocking supervisor such that the average cost per task in the worst-case is minimized. To solve the problem, we propose a game-theoretical approach by converting the optimal control problem as a two-player graph game. Structural properties of the converted game

are discussed. In particular, we show that this game can be solved by a set of mean payoff decision problems, for which effective algorithms exist. Our problem can be considered as a special instance of the general ratio-game in the literature. However, by exploring new structural property for this problem, we achieve superior computational efficiency when compared to the conventional solution designed for more general problem formulations. Illustrative examples are provided to demonstrate the proposed algorithm.

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1.4. IEEE Control Systems Letter

Volume: 8, Issue: 5, June 2024

- **On the Existence of Simulations for Max-Plus Automata**
  Authors: Bérangère Daviaud ; Sébastien Lahaye ; Mehdi Lhommeau ; Jan Komenda
  Abstract: The concept of weighted simulation has recently been defined for max-plus automata. This paper contributes to identifying the structural conditions for which a weighted simulation might exist. In particular, it provides verifiable sufficient conditions for the existence of a weighted simulation.

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1.5. International Journal of Control

Volume: 97, Issue: 6, June 2024

- **Modeling and state estimation for supervisory control of networked timed discrete-event systems and their application in supervisor synthesis**
  Authors: Yunfeng Hou ; Yunfeng Ji ; Gang Wang ; Ching-Yen Weng ; Qingdu Li
  Abstract: This paper considers modeling and state estimation of timed discrete-event systems (TDESs) with communication delays and losses. In the previous framework, the specified closed-loop system language may contain physically impossible strings, i.e. strings never occur in practice. To exclude these physically impossible strings, this paper presents a new modeling framework for supervisory control of networked TDESs. Specifically, we first analyse how to model and update the observation channel and the control channel under communication delays and losses. We then construct an automaton that explicitly describes the interaction process between the plant and the supervisor over the observation channel and the control channel so that the language of the closed-loop system can be specified. Compared with the existing work, the proposed framework can model the 'dynamics' of the closed-loop system more accurately. Under the proposed framework, we further estimate states of the closed-loop system under communication delays and losses. The state estimation is implemented on-the-fly and bases on only the information of observations and controls in history. As an application of the proposed modeling and state estimation approaches, we finally extend the existing approaches to find all the admissible and safe supervisors of networked TDESs.
- **Two-staged approach for estimation of sequences in partially observable P-time Petri nets on a sliding horizon with schedulability analysis**
  Authors: P. Declerck ; P. Bonhomme
  Abstract: In this paper, we consider the on-line estimation of current subsequences for Partially Observable P-time Petri Nets and their starting markings on a sliding horizon composed of steps defined by two successive occurrences of observable transition firings. We propose a general strategy composed of two phases: Phase 1 exploits a simplification of the P-time Petri net under the form of a Timed Petri net; considering a candidate count vector and the relevant starting marking proposed at Phase 1, Phase 2 makes a schedulability analysis by building a system of relations which can be represented by an acyclic conflict-free computation graph. The complete approach avoids the generation of sets which is generally time and space consuming, and provides an optimal solution for each subproblem by using efficient standard tools.

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1.6. IEEE Transactions on Systems, Man, and Cybernetics: Systems

Volume: 54, Issue: 6, June 2024

- **Minimum Initial Marking Estimation in Labeled Petri Nets With Unobservable Transitions Based on Minimal Explanations**
  Authors: Hao Yue ; Yakun Xu ; Keyi Xing ; Hesuan Hu ; Shanchen Pang
  Abstract: Marking estimation is crucial in the area of discrete event systems. This paper proposes algorithms for addressing the problem of minimum initial markings (MuIMs) estimation in a known Petri net (PN) structure. The existence of unobservable transitions makes this problem challenging since the number of transition sequences consistent with an observed label sequence can potentially be infinite. It is assumed that only minimal explanations can fire before the firing of each observable transition (OT). We present the definition of minimal explanation places, which allows potential minimal explanations to fire before the firing of each OT to obtain more minimal initial markings. Since the number of initial markings may be infinite, we aim to obtain the initial markings that not only enable at least one transition sequence consistent with both the observed label sequence and the PN structure, but also exhibit the minimum total number of tokens (i.e., the minimum total number of tokens when summed over all places). After developing the algorithms, we also propose two heuristic methods to reduce the computational cost, resulting in a subset or an approximation of the final MuIMs. An illustrative example is provided to indicate how the proposed algorithms and heuristics can be utilized to reveal the minimum number of resources required which are indispensable at the initial state for the completion of a specified task sequence.
- **Reachable Region-Based Filtering of Markov Jump Piecewise-Affine Systems With Bounded Disturbance**
  Authors: Zepeng Ning ; Zeyuan Xu ; Jun Song ; Choon Ki Ahn
  Abstract: This article develops a new filtering strategy for discrete-time Markov jump nonlinear systems approximated via a piecewise-affine (PWA) model. Motivated by the existence of certain partitioned regions that the system state cannot enter within one time step, an algorithm for calculating the reachable target regions for the system state is provided from the currently located region by allowing for bounded disturbance. Then, we analyze the stochastic stability with a desired disturbance-attenuation performance index for the resulting filtering error system (FES) by eliminating all the unreachable regions from target regions at the next time step. In contrast to traditional methods regardless of their unreachable regions, our results can reduce both the computational burden and the conservativeness of the analysis results. In addition, a PWA filter is designed, which excludes all the impossible target regions, such that the FES is stochastically stable, satisfying disturbance-attenuation performance with a lighter computational burden. The validity and advantages of our proposed filtering strategy are verified via a tunnel diode circuit.

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2 Conferences

Contributed by: Xiang Yin (yinxiang@sjtu.edu.cn)

2.1 **2024 IFAC Conference on Analysis and Design of Hybrid Systems (ADHS)**
Boulder, Colorado, July 1-3, 2024.
https://www.colorado.edu/conference/adhs2024/

2.2 **2024 American Control Conference (ACC)**
Toronto, Canada, July 8-12, 2024.
https://acc2024.a2c2.org/

2.3 **The IEEE Conference on Control Technology and Applications (CCTA)**
Newcastle upon Tyne, UK, August 21-24, 2024.
https://ccta2024.ieeecss.org/

2.4 **2024 International Conference on Automation Science and Engineering (CASE)**
Bari, Italy, August 28-September 1, 2024.
https://www.ieeesmc2024.org/

2.5 **2024 International Conference on Systems, Man, and Cybernetics (SMC)**
Sarawak, Malaysia, October 7-10, 2024.
https://www.ieeesmc2024.org/

2.6 **2023 IEEE Conference on Decision and Control (CDC)**
Milan, Italy, December 16-19, 2024.
https://cdc2024.ieeecss.org/

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3 Books

3.1 Graph-Theoretical Methods in Systems Theory and Control

Author: Jan Lunze, Ruhr-University, Germany

Description: The book describes for numerous scenarios how to use the structural properties of a system represented by a graph to simplify modelling, analysis, and design tasks. For example, block diagrams and coupling graphs can be used to decompose systems, automata graphs to analyse discrete-event systems and Markov chains, structure graphs to find generic properties of linear systems or communication graphs to design networked control systems. The book includes many examples derived from diverse fields of application, exercises with solutions and MATLAB scripts to implement graph-theoretical methods for systems analysis

Additional information on the book can be found at
www.editionmora.de/gmsc

The book is produced as "print-on-demand" and can be ordered directly at the printer:
https://publish.bookmundo.de/books/349971

3.2 Safe Autonomy with Control Barrier Functions: Theory and Applications

Authors: Wei Xiao, Christos G. Cassandras, and Calin Belta

Description: The book presents the concept of Control Barrier Function (CBF), which captures the evolution of safety requirements during the execution of a system and can be used to enforce safety. Safety is central to autonomous systems since they are intended to operate with minimal or no human supervision. The book includes both theoretical and application perspectives on how safety can be guaranteed. It explains how the CBF approach is computationally efficient and can easily deal with nonlinear models and complex constraints used in a wide spectrum of applications, including autonomous driving, robotics, and traffic control. Safety guarantees can be integrated into the operation of such autonomous systems, including typical safety requirements that involve collision avoidance, technological system limitations, and bounds on real-time executions. Adaptive and event-driven approaches for safety are also discussed for time-varying execution bounds and noisy dynamics, as well as for systems with unknown dynamics.

Additional information on the book can be found at
https://link.springer.com/book/10.1007/978-3-031-27576-0
where an eBook version can also be downloaded (free for some educational institutions).

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4 Software Tools

4.1 Eclipse ESCET™ version 3.0 release

The Eclipse Supervisory Control Engineering Toolkit (Eclipse ESCET) project provides a model-based approach and toolkit for the development of supervisory controllers. It includes the languages CIF, Chi and ToolDef. ESCET, initially developed by Eindhoven University of Technology, is since January 2020 an Eclipse Foundation open-source project. More information can be found on the toolkit's website at https://www.eclipse.dev/escet/.

In March 2024, ESCET version 3.0 has been released and can be downloaded from https://www.eclipse.dev/escet/download.html. The main changes in this version are

- ESCET now has a logo. So the appearance of the application might be different from what you are used to (only Windows for now, macOS and Linux will follow soon).
- Several improvements to the (still experimental) new CIF PLC code generator have been included.
- The CIF code generator for HTML files and JavaScript code has received several (performance) improvements and bug-fixes.
- SVG input mappings can now either assign values to input variables (new feature), or map to an event to take (existing feature). This new feature is currently an experimental work-in-progress language feature, and is not yet supported by all CIF tools.
- All CIF tools now support reading .cifx files, CIF files in an XML format. CIF tools that write CIF specifications also support writing .cifx files. See the CIF reference manual for more information. Similarly, the ToolDef interpreter now supports reading .tooldefx files, ToolDef files in an XML format.
- The CIF benchmark models have been extended with the mri_event, mri_state and wafer_scanner benchmark models.

The full ESCET release notes, including links to the language specific release notes and release notes from previous versions, are available from https://www.eclipse.dev/escet/release-notes.html.

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