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Introduction to the special issue on runtime verification

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Abstract This article introduces the extended versions of selected papers from the refereed proceedings of the 16th International Conference on Runtime Verification (RV 2016) held in Madrid, Spain, in September 2016. Runtime verification encompasses all aspects of monitoring and analysis of hardware, software, and system executions in general. Runtime verification techniques are lightweight dynamic techniques to assess and enforce correctness, reliability, and robustness during system execution. These techniques are significantly more powerful and versatile than conventional testing, and more practical than exhaustive formal verification (at the price of incomplete coverage).

Keywords Runtime verification · Monitoring · Reliability · Trace · Instrumentation

1 Runtime verification

Runtime verification (RV) is the umbrella term to encompass all aspects of monitoring and analysis of hardware, software and the executions of systems in general. RV techniques are lightweight dynamic techniques to assess and enforce correctness, reliability, and robustness during system execution. These techniques are significantly more powerful, versatile and

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rigorous than conventional testing, and more practical than exhaustive formal verification. Foundational papers on RV include [1–5]; see also [6–11] for tutorial papers. Recently, a tutorial book on RV has been released [12] presenting introductory and advanced topics, including the monitoring of cyber-physical systems [13], runtime failure prevention and reaction [14], monitoring concurrency errors [15], monitoring decentralized and distributed systems [16], and financial and transaction systems [17].

In the last decade, runtime verification, as a computer science field, has grown significantly. As an event, RV—which started initially as a workshop—became a conference in 2010 [18]. Three competitions on software for runtime verification have been organized in so far (see [19–21] and [22] for an extensive report of the first incarnation of the competition) as well as a workshop reporting reflections on past competitions [23]. Additionally, two graduate schools (see [24]) devoted to runtime verification have been recently organized in 2016[1] and 2018.[2] A European COST Action on Runtime Verification (IC 1402, runtime verification beyond monitoring[3]) is ongoing with the objectives of connecting runtime verification to other analysis techniques, and expanding the applicability of RV beyond software reliability. Workshops on particular aspects of runtime verification have also flourished: the AD-RV track [25,26] at ISoLA 2014[4] on general applications of runtime verification, the iAD-RV [27] track on industrial applications of runtime verification at ISoLA 2016,[5] the PrePost workshop on pre and post deployment technique in 2016, and the recent RUME[6] and VORTEX[7] workshops on embedded systems and object-oriented languages, respectively.

As the area is getting increasingly mature, deeper results are generated tackling more complex problems. This special issue contains extended versions of selected papers from the RV 2016 conference, as a witness to this maturity.

2 Summaries of the selected articles

In this section, we briefly summarize the articles contained in this special issue. All articles are significantly extend the corresponding papers from the refereed proceedings [28] of the 16th International Conference on Runtime Verification, RV 2016, held in Madrid, Spain, in September 2016.

Goubault-Larrecq and Lachance [29] use monitoring for intrusion detection via their tool Orchids. Their paper addresses the problem of determining the complexity of monitoring an Orchids signature (a specification) and provide a linear-time algorithm that determines whether the number of monitors for this specification is linear or exponential in the number of events.

Shi et al. [30] validate at runtime wireless protocol using wireless sniffers to avoid device instrumentation. They address the problem of losses caused by wireless propagation which prevents the construction of complete traces. Protocols are expressed as a state machine which encodes the uncertainty of sniffers by adding non-determinism. The validation problem is framed as a decision problem, shown to be NP-complete, and they provide an algorithm for

[1] www.rv2016.imag.fr/?page_id=128.

[2] www.cost-arvi.eu/?page_id=1163.

[3] www.cost-arvi.eu.

[4] www.cs.uni-potsdam.de/gsse/www.isola-conference.org/isola2012/.

[5] isola-conference.org/isola2016/.

[6] beru.univ-brest.fr/RUME18.html.

[7] conf.researchr.org/track/vortex-2018/vortex-2018-papers.

exhaustively exploring mutated traces. The algorithm can be enhanced by protocol-oblivious heuristics to select most likely mutated traces.

Kauffman et al. [31] infer abstractions of event streams produced by telemetry systems of the Curiosity rover on Mars. Their approach introduces a hierarchy of event abstractions that can be queried and visualized. Event abstractions are expressed as a rule-based system inspired by Allen's temporal logic. The approach is implemented in both the C and the Scala programming languages and the specification formalism as both internal and external domain-specific languages.

Jakšić et al. [32] monitor the physical behavior of cyber-physical systems. They provide a quantitative semantics of Signal Temporal Logic by introducing a weighted edit distance. The decision procedure is a dynamic programming algorithm which allows quantifying the similarity between the system and specification behaviors. Hardware-based monitors are implemented on an FPGA, assessed on automotive benchmarks, and used on a magnetic sensor of modern cars.

Moreno and Fischmeister [33] enforce the safety and security of embedded systems using power consumption. Their approach is non-intrusive and consists in analyzing the signal and the system using a spectral analysis that matches the input and output signal. The approach leverages the control-flow graph of the program for performance improvement. They present experiments on a SCADE application and a case study where anomalous executions are detected.

Roşu [34] introduces a sound and complete direct proof system for linear-temporal logic with (only) finite traces. The proof system consists of seven rules extending the proof system of propositional logic, six rules are rather expected, and one special rule is of coinductive nature. Roşu shows that this rule is strictly more powerful than the classical inductive rule used in existing proof systems for infinite and infinite-finite traces.

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