ExoDPOR: Exogenous Stateless Model Checking

Lars Tveito, Einar Broch Johnsen and Rudolf Schlatte

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Department of Informatics, University of Oslo
{larstvei,einarj,rudi}@ifi.uio.no

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- We have instantiated ExoDPOR for Real-Time ABS

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  - But is rarely feasible

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  - Requires a runtime with backtracking
  - DPOR algorithms are generally sequential and challenging to parallelize

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- ExoDPOR allows us to benefit from the Erlang backend of Real-Time ABS
- A change in the Erlang backend does not imply that a change is needed in the ExoDPOR instantiation
- Much easier to support the full language

LTS and Traces

- We assume a *labeled transition system* (LTS), $(\mathcal{S}, \mathcal{E}, \rightarrow)$, where $\mathcal{S}$ is a set of states, $\mathcal{E}$ a set of events, and $\rightarrow \subseteq \mathcal{S} \times \mathcal{E} \times \mathcal{S}$ the transition relation

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- An *execution trace* is a sequence of events, denoted $\tau = e_1 \cdot e_2 \cdots e_n$

Record & Replay semantics

$$\frac{\sigma \to \sigma'}{\langle \tau_{\bullet} \mid \tau_{\blacktriangleright} \rangle \triangleright \sigma \xrightarrow{\bullet/\blacktriangleright} \langle \tau_{\bullet} \mid \tau_{\blacktriangleright} \rangle \triangleright \sigma'} \quad (\textsc{Unlabeled Record \& Replay})$$

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$e_i \overset{HB}{\Longrightarrow}_\tau e_j$	if e_i occurs before e_j in the trace τ and $e_i \overset{MHB}{\Longrightarrow} e_j$ or $e_i \star e_j$.
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  Two traces τ_1 and τ_2 are *equivalent*, denoted $\tau_1 \simeq \tau_2$, if $\overset{HB}{\Longrightarrow}_{\tau_1} = \overset{HB}{\Longrightarrow}_{\tau_2}$.

Exogenous exploration

$$\frac{}{\langle exo : \{\tau\} \cup Seeds, \{w\} \cup W, \mathcal{S}s\rangle \rightarrow \langle exo : Seeds, W, \mathcal{S}s\rangle \ \langle w : \langle \varepsilon \mid \tau\rangle \triangleright \sigma_0\rangle} \text{(Explore-single-trace)}$$

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$$\text{(Worker-progress)}$$
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(Update-with-explored-trace)

$$\frac{\mathcal{S}s' = addTrace(\mathcal{S}s, \tau) \quad Seeds' = Seeds \cup newSeeds(\mathcal{S}s', \tau)}{\langle exo : Seeds, W, \mathcal{S}s\rangle \ \langle w : \langle \tau \mid \varepsilon\rangle \triangleright \sigma_\varepsilon\rangle \rightarrow \langle exo : Seeds', \{w\} \cup W, \mathcal{S}s'\rangle}$$

Framework

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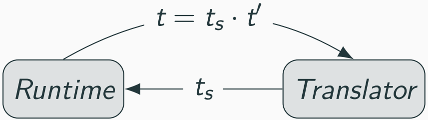

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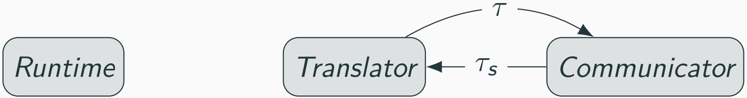

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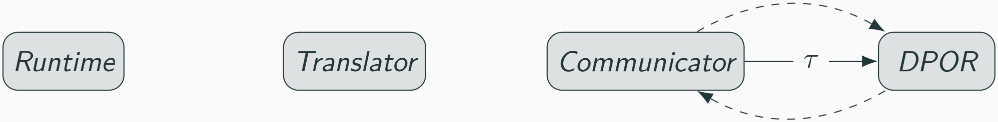

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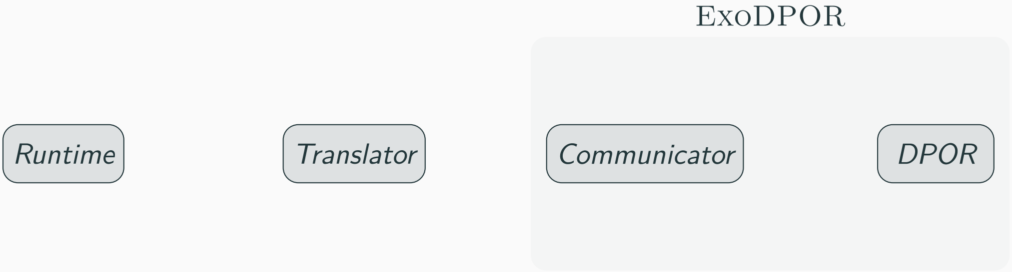

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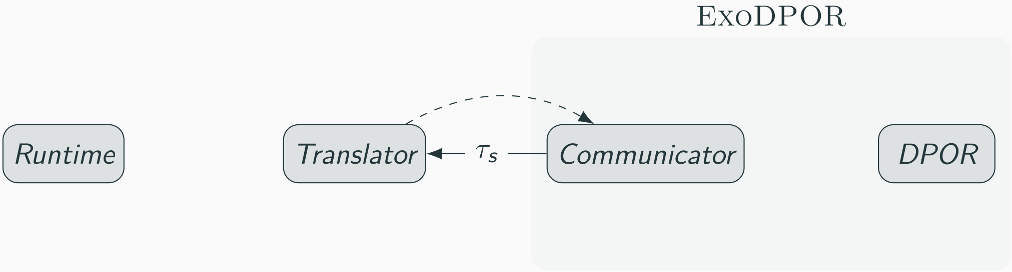

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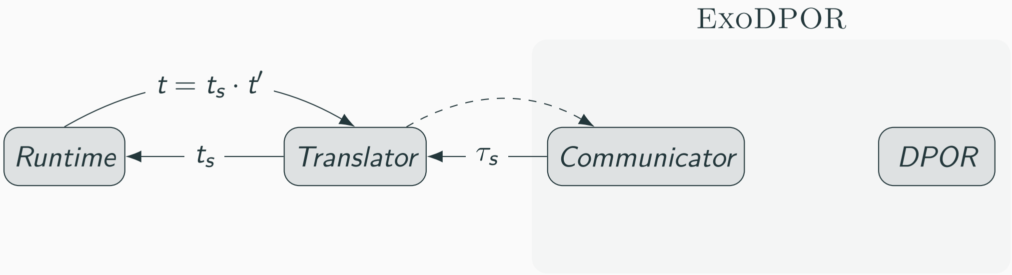

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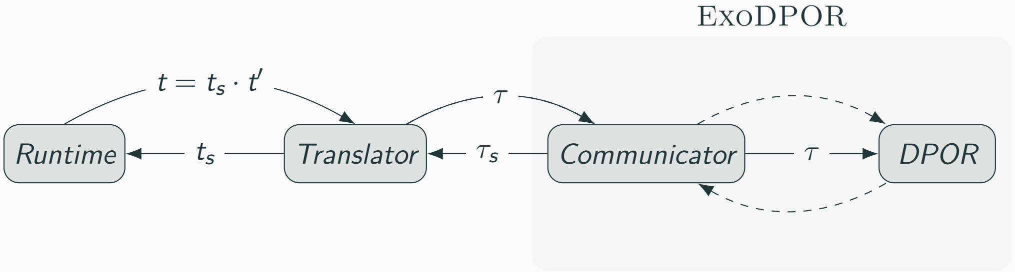

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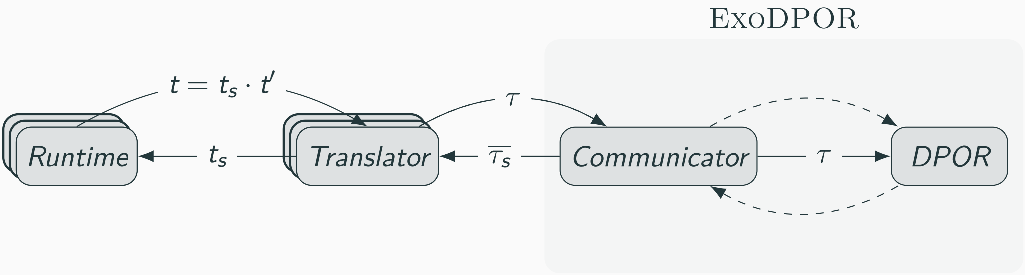

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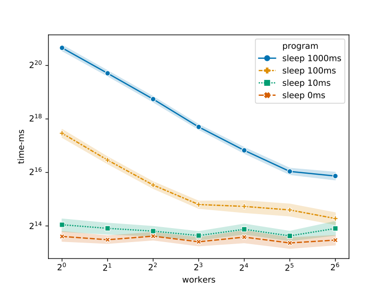

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- It has been instantiated for Real-Time ABS
- We believe an instantiation for ExoDPOR is significantly easier than to implement a model checker from scratch
- Experiments indicate that parallelization gives a linear speed-up for long-running programs