Towards Soundness-Preserving Composition with Portable Nets

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Abstract

Soundness is a key correctness criterion in Petri Net-based workflow models, yet it is not guaranteed to be preserved under composition of two disjoint sound nets. In this work, we tackle this problem and build on Portable Nets (P-Nets), a class of Petri Nets that generalizes soundness. We investigate how P-Nets can be composed in a soundness-preserving manner using an existing compositional operator such that the resulting net remains sound by design.

Keywords

Petri Nets, Portable Nets, Soundness, Composition

Workflow Nets (WF-Nets) [1], a subclass of Petri Nets [2], provide a well-established mathematical framework for modeling and analyzing business processes. A key aspect of such analysis is soundness [1], a fundamental behavioral correctness criterion for WF-Nets. While literature [3] identifies composition as an essential modeling technique, the composition of two sound WF-Nets does not necessarily yield a sound composite model [4].

To address this limitation, we employ Portable Nets [5] (P-Nets), a class of Petri Nets that has shown promising results in the generalization of soundness, for soundness-preserving composition. In this work, we leverage these properties to enable soundness-preserving composition. Specifically, we demonstrate that the composition of two disjoint P-Nets — using the composition operator of [3] — results in a composite P-Net that is sound by design.

Background A Petri Net N = (P, T, F) is a P-Net if there is a set of source places $P_i \subset P$, such that $\forall\, p_i \in P_i : \bullet\, p_i = \emptyset$, there is a set of sink places $P_o \subset P$, such that $\forall\, p_o \in P_o : p_o\bullet = \emptyset$, the sets P_i and P_o are pairwise disjoint, and $\forall\, x \in P \cup T$: x is on the path from at least one $p_i \in P_i$ to at least one $p_o \in P_0$. A P-Net System $\Omega = (N, M_i)$ is a P-Net N with an initial marking $M_i := \forall\, p_i \in P_i$: $M_i(p_i) = 1 \wedge \forall\, p \in P \setminus \{P_i\}$: $M_i(p) = 0$. Let $[N, M_s\rangle$ be the set of reachable markings of Ω. $M_f \in [N, M_s\rangle$ is called final marking of Ω, if $\forall\, p_o \in P_o\ (\subset P) : M_f\,(p_o) = 1$ and for all $p \in P \setminus \{P_o\} : M_f\,(p) = 0$. Ω is sound, if for any reachable marking $M_1 \in [N, M_s\rangle$ starting from M_i, it is possible to reach the final marking M_f. Formally, $(N, M_i)\ [\sigma\rangle\ (N, M_1)\ [\sigma\rangle\ (N, M_f)$, where $[\sigma\rangle$ denotes a sequence of firing transitions $t_i \in T = t_1,t_2,\ldots t_n$ with $n \in \mathbb{N}$, such that $[\sigma\rangle$ leads from M_i over M_1 to M_f, and there are no dead transitions. Next to N, we define $\overline{N} = (\overline{P}, \overline{T}, \overline{F})$ as a

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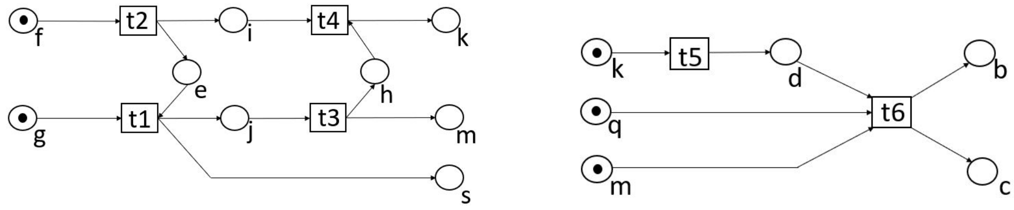

(a) Portable Net N (b) Portable Net $\overline{N}$

Figure 1: Portable Net N = (P, T, F) used to compose with Portable Net $\overline{N}$ = ($\overline{P}$, $\overline{T}$, $\overline{F}$)

P-Net with an initial marking M_2, see Figure 1.

Composition of Portable Nets Given N and $\overline{N}$, which are sound based on the generalized soundness notion [5], we demonstrate the following result: The composition of N and $\overline{N}$, denoted by $N \otimes \overline{N}$ and shown in Fig. 2, preserves soundness by design. To this end, we employ the composition operator presented in [3], which ensures associativity for composition.

Any P-Net consists of two components (i.e., subnets): an inner component and an interface component. While inner components are parts of a P-Net that are not affected by composition, interface components are directly affected by composition. An interface component consists of labelled ports. A port is a subnet of labelled elements within an interface component and serves as the gluing point for the composition with a port of another P-Net. A port of a P-Net is composable with a port of another P-Net if and only if both ports contain at least one equally labelled element. During composition, equally labelled elements of both ports become inner elements of the composed net. Elements that are not equally labelled become ports of the composed net. In this way, two disjoint P-Nets can be composed while retaining soundness.

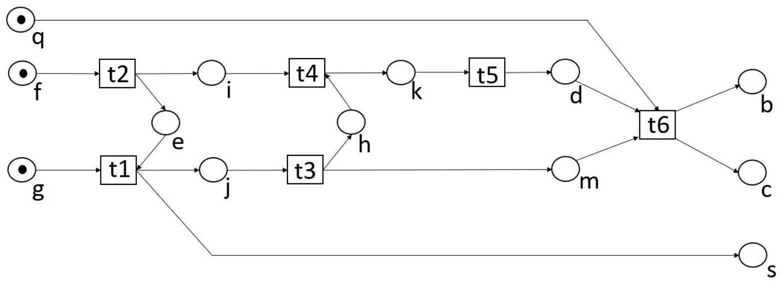

Figure 2: Sound composed Portable Net $N \otimes \overline{N}$ = (P', T', F') based on N and $\overline{N}$.

For our running example, we compose place k of N with place k of $\overline{N}$ and m of N with m of $\overline{N}$. Hence, these places, k and m of $\overline{N}$, serve as interface components for the composition with N. The composed P-Net $N \otimes \overline{N}$ remains sound exactly like its origin nets N and $\overline{N}$. Note that the composition of transitions is likewise applicable but not listed. Due to space restrictions, we omit the application of the verification scheme of soundness from [5] for the composed net N

$\otimes \overline{N}$.

Related Work The idea of soundness-preserving composition of Petri nets is not new [6, 7, 8, 9, 10, 11, 12], among others. In this work, we employ the soundness notion of [5], which generalizes the classical notion by relaxing the structural restrictions of WF-Nets, such as having a single source and sink place. None of the referenced works investigates soundness-preserving composition under this generalized notion.

Conclusion We demonstrated, using an example, how the proposed soundness notion may be retained during the composition of two sound P-Nets using an existing composition operator. In future work, we aim to explore the general compositionality of arbitrary P-Nets that preserve the proposed notion of soundness producing a P-Net as a result. Moreover, we aim to establish refinement relations between High-Level and Low-Level P-Nets, allowing for systematic refinement or abstraction while preserving soundness. Additionally, we plan to investigate whether soundness of P-Nets can be decided in polynomial time.

Declaration on Generative AI

The author(s) have not employed any Generative AI tools.

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