GTAEXPRESS: a Software Package to Handle Kronecker Descriptors

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Abstract—This paper presents a software package, called GTAexpress, to handle structured continuous-time Markovian models expressed using Generalized Tensor Algebra, also known as, Kronecker descriptors. The proposed software package has the most advanced methods to provide stationary and transient solutions as well as some basic structural properties of models represented as a sum of generalized tensor products. Other software tools already provide some approaches based on tensor representation, like, PEPS and SMART. However, such tools are bounded to a specific modeling formalism. The basic idea of GTAexpress is to provide Kronecker descriptor-based solutions that can be easily used as a package in new tools or as a library in the existing high-level formalisms tools.

Keywords—Kronecker descriptors; Numerical solution;

I. INTRODUCTION

The definition of a tensor representation has been a subject of interest for many continuous-time Markovian structured formalisms. The most traditional advantage of tensor representations is to reduce significantly the model storage needs of rather large systems (over a million states). Such advantage has been accentuated with the use of generalized tensor algebra and recently efficiency improvements of the vector-descriptor multiplication algorithms [1] have extended the benefits to a faster solution than traditional approaches [2].

The Stochastic Automata Networks (SAN) formalism [2] was defined in a very close relation with the tensor representation implemented in the PEPS software tool [3]. The Stochastic Petri Nets (SPN) [4] in their standard form, or more often in the Generalized form (GSPN) [5] were subject to some efforts to find an efficient tensor representation [6] in the SMART software tool [7]. This was also the case of the Performance Evaluation Process Algebra (PEPA) formalism [8] to whom a tensor representation was proposed [9], but it is not yet available at the PEPA Plugin solver [10]. In parallel with that, the techniques to handle tensor representations are evolving and it is hard to keep each specific tool up-to-date with the new improvements unless one proposes a multipurpose software package containing the solutions to models described as a continuous-time Descriptor, i.e., a sum of generalized tensor product terms.

We present the GTAEXPRESS package, a command-line software that is a dedicated library to deal with tensor representations. The advantages are firstly related to providing a formalism-independent tool that is available to tool developers with as little effort as possible. Secondly, the goal is to provide a reliable and efficient code according to the latest research developments for tensor representations.

II. GENERAL DESCRIPTORS AND APPLICATIONS

A descriptor for a model defined by a continuous-time structured formalism assumes that: (i) the structured model is composed by a certain number \( N \) of components; (ii) these components have a set of states, called local states; (iii) the state space is the Cartesian product of the local states of its components; (iv) the transitions between states can occur in a completely local manner (it occurs in one component and it is neither affected, nor it affects the other components), partially local manner (it occurs in one component according to the current state of other components) or synchronized manner (it affects the local state of more than one component). Structured formalisms such as SAN, SPN and PEPA, all have a tensor representation already defined [2], [11], [9] in a quite straightforward way to obtain an efficient Kronecker-based descriptor.

General assumptions being made, a compiler shall translate the models to the proper GTAEXPRESS format: (i) a descriptor is composed of a sum of tensor products divided in two parts; (ii) there is a part describing the local transitions; (iii) there is a part describing the synchronized transitions. The completely local transitions

1 Some of the cited formalisms can be used in both continuous and discrete-time versions. However, GTAEXPRESS at the present time only deals with models that considers continuous-time.
are all described in the local part of the descriptor. The synchronized transitions are all described in the synchronizing part of the descriptor. According to the formalism, and even with the modeling style, some partially local transitions may appear either in the local, or in the synchronizing part of the descriptor.

Considering that a high-level formalism presents specific primitives one must adapt them to the general descriptor concepts. For SAN, there is a clear relation between the descriptor and the model itself that presents specific gains and advantages on its use. However, it is also important to extract performance indexes from the models and infer insightful conclusions as fast as possible. The present work is a step towards this objective since it will allow a model to be defined in a large set of formalisms and have the corresponding results obtained in a timely manner using the package efficient solution mechanisms. Readers interested in details about this package may find a documentation accessing the GTAEXPRESS software tool webpage at http://www.inf.pucrs.br/peg/gtaexpress.html.

REFERENCES