Balancing-related model reduction of large-scale sparse systems in MATLAB and Octave with the MORLAB toolbox

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The modeling of real-world applications often results in linear dynamical systems of the form

$$\begin{aligned} E\dot{x}(t) &= Ax(t) + Bu(t),\\ y(t) &= Cx(t) + Du(t), \end{aligned} \tag{1}$$

with $E, A \in \mathbb{R}^{n \times n}$, $B \in \mathbb{R}^{n \times m}$, $C \in \mathbb{R}^{p \times n}$ and $D \in \mathbb{R}^{p \times m}$, described by a large number n of differential and algebraic equations. Model order reduction is the remedy to construct cheap-to-evaluate surrogates of similar structure to (1) by reducing the number of describing equations to $r \ll n$.
For the use of model reduction methods in practice, potentially by users who may have never been introduced to the underlying theory, efficient implementations of these methods with intuitive interfaces are needed. The MORLAB, Model Order Reduction LABoratory, toolbox [1] has been providing such implementations in MATLAB and Octave mainly for balancing-related model reduction, e.g., balanced truncation, for the case of medium-scale ($n \in \mathcal{O}(10^3)$), dense systems (1). The underlying spectral projection methods allow for fast and accurate computations, even able to handle general cases of differential-algebraic equations describing (1). The toolbox is open source and freely available, has a unified framework for all implemented methods that allows for quick exchanges of routines and easy comparisons between methods, and it is portable to all different operating systems on which bare MATLAB and Octave installations are available. However, in many applications, especially in the context of discretized partial differential equations, the coefficient matrices in (1) are of large scale ($n \in \mathcal{O}(10^5)$ and larger) and sparsely populated. Efficient large-scale sparse matrix equations solvers, such as those provided in the Matrix Equation Sparse Solvers (M-M.E.S.S.) library [2], are the key to extend the balancing-related model reduction MORLAB routines to this system case.
This poster describes the latest release, version 6.0, of the MORLAB toolbox. It features new implementations of balancing-related model reduction methods for large-scale sparse, linear systems, using the Lyapunov and Riccati equation solvers from the M-M.E.S.S. library as their backbone.

References

[1] P. Benner and S. W. R. Werner. MORLAB – Model Order Reduction LABoratory. See also: `https://www.mpi-magdeburg.mpg.de/projects/morlab`.

[2] J. Saak, P. Benner, and M. Köhler. M-M.E.S.S. – The Matrix Equation Sparse Solvers library. See also: `https://www.mpi-magdeburg.mpg.de/projects/mess`.