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Geometric Algebra, Extended Cross-product and Laplace Transform for Multidimensional Dynamical Systems

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Abstract. This contribution describes a new approach for solving linear system of algebraic equations and differential equations using Laplace transform by the extended-cross product. It will be shown that a solution of a linear system of equations Ax=0 or Ax=b is equivalent to the extended cross-product if the projective extension of the Euclidean system and the principle of duality are used. Using the Laplace transform differential equations are transformed to a system of linear algebraic equations, which can be solved using the extended cross-product (outer product). The presented approach enables to avoid division operation and extents numerical precision as well. It also offers applications of matrix-vector and vector-vector operations in symbolic manipulation, which can leads to new algorithms and/or new formula. The proposed approach can be applied also for stability evaluation of dynamical systems. In the case of numerical computation, it supports vector operation and SSE instructions or GPU can be used efficiently.

Keywords: Linear system of equations, linear system of differential equations, Laplace transform, extended cross product, outer product, homogeneous coordinates, duality, geometrical algebra, dynamic systems, stability, GPGPU computation, SSE instructions.

1 Introduction

Solving system of linear algebraic equations is often used in many applications. However, methods for solution differ if the linear system of equations is homogeneous, i.e. $\boldsymbol{Ax} = \boldsymbol{0}$, or non-homogeneous $\boldsymbol{Ax} = \boldsymbol{b}$. If the projective extension of the Euclidean space is used and principle of duality applied, the both cases can be solved using extended cross-product as $\boldsymbol{\alpha}_1 \times \boldsymbol{\alpha}_2 \times \ldots \times \boldsymbol{\alpha}_n$ or as $\boldsymbol{\alpha}_1 \wedge \boldsymbol{\alpha}_2 \wedge \ldots \wedge \boldsymbol{\alpha}_n$ if outer product is used, where $\boldsymbol{\alpha}_i$ is the i −th row of the matrix $\boldsymbol{A}$, resp. $[\boldsymbol{A}| - \boldsymbol{b}]$ [10]-[18].

In the case of differential equations, the Laplace transform transforms differential system to an algebraic system of equations. It can be seen that the extended cross-product does not use any division operation as would be expected in solution of a linear

adfa, p. 1, 2011.

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