IEEE P1076.1 Working Group
Requirements for Matrix/Vector Support

History:
v0.1 Zhichao Deng / June 7, 2010 Initial draft.
v0.2 Zhichao Deng / Aug 18, 2010 Updated to include changes from two meetings.
v0.3 Zhichao Deng / Sep 29, 2010 Updated to include changes from meeting.
v0.4 Zhichao Deng / Oct 24, 2010 The final draft version.

IEEE recommendations on word usage
----------------------------------
shall means is required to
should means is recommended that
may means is permitted to
can means is able to

Purpose
-------
Matrix/Vector operations allow models with equations with a pre-defined matrix/vector operator. Such support allows all the frequently used operators envolving matrix/vector.

Scope
-----
To develop VHDL-AMS package(s) and/or new language constructs that support the required functionality.

General Requirements
---------------------
MVS-R1 [shall]
Matrix/vector operations are defined as reference in a standard package.
The package will only cover 2-D matrix or vector since the multi-dimension matrix seem not being used quite often in the modeling world.

Matrix Definition
-----------------
MVS-R2 [shall]
The package(s) shall provide the ability to describe matrix of real and complex type.

MVS-R3 [shall]
The package(s) shall provide the ability to describe matrix of non-floating type such as integer, boolean, physical type.
Matrix/vector Construction/access

------------------------
MVS-R4  [shall]
The package(s) shall provide the ability to get sub-matrices out of and put sub-matrices into a matrix (support block matrix manipulation). For example, matrix/vector slicing.

MVS-R5  [shall]
The package(s) shall provide the ability to construct a diagonal matrix with a vector of the diagonal element. Example: identity matrix construction
The package(s) shall provide the ability to construct a matrix with all the elements to be the same element specified by the user. Example: zero or unity matrix construction

Matrix/vector Operations

------------------------
MVS-R7  [shall]
The package(s) shall provide the addition, subtraction, multiplication, division, exponentiation operators of matrix elements.

MVS-R8  [shall]
The package(s) shall provide dot product between matrix-matrix and matrix-vector.
\[ \mathbf{a} \cdot \mathbf{b} = \mathbf{a}^\mathsf{T} \mathbf{b}, \]
The package(s) shall provide cross product between two 3-vectors.
\[ \mathbf{a} \times \mathbf{b} = c \hat{\mathbf{n}} \]

MVS-R9  [shall]
The package(s) shall provide transpose, conjugate transpose (complex), complex conjugate (complex) for matrix and vector.

MVS-R10  [shall]
The package(s) shall provide determinant computation for matrix and vector.

MVS-R11  [shall]
The package(s) shall provide matrix power operation.
Example: MatrixPower(A, 3) = A * A * A
A is a matrix

MVS-R12  [shall]
The package(s) shall provide matrix exponential operation.
Example: MatrixExponential(A) = \exp(A)
A is a matrix

MVS-R13  [shall]
The package(s) shall provide vector norm operation for 1, 2, and infinite norm.
MVS-R14  [shall]
The package(s) shall provide matrix 1-norm operation.
Rationale: the matrix 1 norm performs the same operation as Matlab.

MVS-R15  [should]
The package(s) should provide matrix trace operation.

MVS-R16  [should]
The package(s) should provide the Kronecker product of matrix.

\[ A \otimes B = \begin{bmatrix}
    a_{11}B & \cdots & a_{1n}B \\
    \vdots & \ddots & \vdots \\
    a_{m1}B & \cdots & a_{mn}B \\
\end{bmatrix}. \]

For example, outer product, a special case of Kronecker product, is used in performing transform operations in DSP. It is also useful in statistical analysis for computing the covariance matrices.

\[ u \otimes v = A = \begin{bmatrix}
    u_1 v_1 & u_1 v_2 & \cdots & u_1 v_n \\
    u_2 v_1 & u_2 v_2 & \cdots & u_2 v_n \\
    \vdots & \vdots & \ddots & \vdots \\
    u_m v_1 & u_m v_2 & \cdots & u_m v_n \\
\end{bmatrix}. \]

MVS-R17  [shall]
The standard shall perform the check for matrix dimension/size during all the matrix operations.

MVS-R18  [may]
The package(s) may provide the matrix inverse operation. But the result from the package definition is not enforced as the correct result by the standard.
Rationale: Due to the nature of numerical accuracy limitation during matrix inverse, the correctness of the matrix inverse is difficult to be defined by the standard.

MVS-R19  [may]
The package(s) may provide a function for calculating a system of linear equations. But the result from the package definition is not enforced as the correct result by the standard.
Rationale: Due to the nature of numerical accuracy limitation during matrix inverse, the correctness of solving a system of linear equation is difficult to be defined by the standard.

Ax = b, where A is a known matrix and b is a known vector. X is the unknown vector to be solved.