NMC Numerical Mathematics Consortium

Summary & Launch Plans

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Spokespeople :

Maplesoft : Dr. Tom Lee

Mathsoft : Lisa-Jean Clifford

National Instruments : Dr. Sugato Deb,
Darren Schmidt

Agenda

- Problem statement
- What standard is being proposed?
- Benefits
- Consortium launch plans
- Future plans
- National Instruments' perspective
- Maplesoft's perspective
- Mathsoft's perspective
- Q&A

Problem Statement

- Users (scientists, engineers, mathematicians) develop algorithms in general-purpose numeric math tools
  - Each have different syntax and interpretation
  - Users cannot easily use algorithms in other tools (portability, specialized tools)
  - Vendors cannot easily use algorithms from other toolchains (custom links to each tool are required)
- Goal: A common foundation enabling algorithm reuse

Reach of Numeric Algorithms

Vertical Consumers of Math Algorithms

Vertical / Specialized Math & Simulation Tools (Visualization, Finite Element Analysis, Signal Processing, Statistics, Business Tools, EDA, MCAD, etc)	Vertical Hardware Targeting/ Programming Tools (VHDL, Verilog, SystemC, C/C++ languages, LabVIEW etc)

Horizontal Math Algorithm Development Tools

Commercial Packages (Maple, Mathcad, Mathematica, MATLAB, etc)	Open Source Packages (Scilab, Octave, RLab, etc)

Example: FFT Representation

Maple

- DiscreteTransforms[FourierTransform] - compute the discrete Fourier transform
- Calling Sequence
- FourierTransform(Z, [,options])
- FourierTransform(Z1, nelem [,options])
- FourierTransform(Zn, dim [,options])
- FourierTransform(X, Y [,options])
- FourierTransform(X1, Y1, nelem [,options])
- FourierTransform(Xn, Yn, dim [,options])
- Parameters
- Z - complex data Array, 1-5 dimensional
- Z1 - complex data Array, 1 dimensional
- Zn - complex data Array, 2-5 dimensional
- X,Y - real data Arrays, 1-5 dimensional
- X1,Y1 - real data Arrays, 1 dimensional
- Xn,Yn - real data Arrays, 2-5 dimensional
- nelem - number of discrete data points to use in the transform
- dim - Array dimension to be transformed
- options - optional argument of the type option=value, where option is one of algorithm, padding, and inplace

Mathematica

- Fourier[list] finds the discrete Fourier transform of a list of complex numbers.

Mathcad

- fft, FFT Return the Fast Fourier Transform of real-valued data in vector v. These functions assume vectors of length 2^m.
- cfft, CFFT Return the Discrete Fourier Transform and Inverse Transform of real or complex-valued data in vector or array A of arbitrary size.

Excel

- The Fourier Analysis tool solves problems in linear systems and analyzes periodic data by using the Fast Fourier Transform (FFT) method to transform data. This tool also supports inverse transformations, in which the inverse of transformed data returns the original data.

Matlab

- FFT Discrete Fourier transform.
- FFT(X) is the discrete Fourier transform (DFT) of vector X. For matrices, the FFT operation is applied to each column. For N-D arrays, the FFT operation operates on the first non-singleton dimension.
- FFT(X,N) is the N-point FFT, padded with zeros if X has less than N points and truncated if it has more.
- FFT(X,[],DIM) or FFT(X,N,DIM) applies the FFT operation across the dimension DIM.

MatrixX

- C = fft(A,{rows,columns,channels})
- fft computes one-dimensional and two-dimensional discrete Fourier transforms.
- Inputs: A A vector, matrix, or PDM. If A is a matrix, a two-dimensional FFT will be computed. If A is a PDM, a two-dimensional FFT will be computed for each dependent matrix. If A is a PDM and the channels keyword is included, one-dimensional FFTs will be computed for each channel.
- rows (Optional) An integer specifying the number of rows the output will have. If the number of rows in matrix A is less than the value of rows, each column vector of A will be zero padded up to the number of rows specified. If the value of rows is less than the actual number of rows in A, an error will occur.
- columns (Optional) An integer specifying the number of columns the output will have. If the number of columns in matrix A is less than the value of columns, each row vector of A will be zero padded up to the number of columns specified. If the value of columns is less than the actual number of columns in A, an error will occur.
- Keywords: channels Specifies that one-dimensional FFTs should be computed on the channels of a PDM. In this mode, zero-padding all channel vectors can be performed by specifying the new length using either the rows or columns keyword.
- Outputs: C The discrete Fourier transform of A.

Example: FFT Representation (Detail)

Mathcad

- t := 0..127
- x := sin(2·π·.01·t)
- w :=fft(x)

Size of w:

Mathcad = 65

MATLAB

- t = 0:127
- x = sin(2*pi*.01*t)
- w = fft(x)

Size of w:

MATLAB = 128

Even if the syntax was identical, the calculations would yield different results. Both are valid interpretations – a standard definition of FFT is required

By definition, the FFT produces a result where the second half of the data is the complex conjugate of the first half. Mathcad uses this and only returns the first half of the data (i.e. N/2 + 1). MATLAB returns all of the data (N).

Example – FFT Semantics (Meaning)

Fast Fourier Transform (FFT) open issues:

- How many elements does it return ?
- How does it handle FFT of a single value, a vector & a matrix ?
- For a complex number, is it doing FFT on the real part only or on both the real and imaginary parts ?
- Is it zero-padding and how ?

The NMC is proposing a standard for core function definitions to clarify the answers to questions such as these

Example – FFT Syntax (Expression)

New technologies introduce new "syntax" models

- **Text**

w = fft(x)

- **Symbolic**

$$f_j = \sum_{k=0}^{n-1} x_k e^{-\frac{2\pi i}{n} jk} \qquad j = 0, \ldots, n-1.$$

- **XML**

```
<block>
 <Fourier_Transform>
        <input>x</input>
        <output>w</output>
 </Fourier_Transform>
</block>
```

- **Graphical Dataflow**

➢ **These are all valid FFT representations and are optimized for different environments**

What is the NMC standardizing?

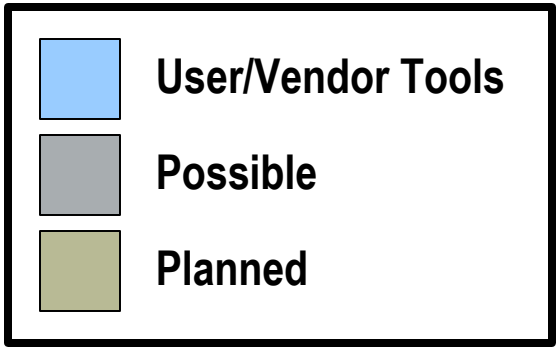
- The NMC is standardizing on function ***Semantics*** (meaning)
  - Inputs, Outputs, Datatypes
  - Easy mapping to transition from functions in one package to another enabling reuse

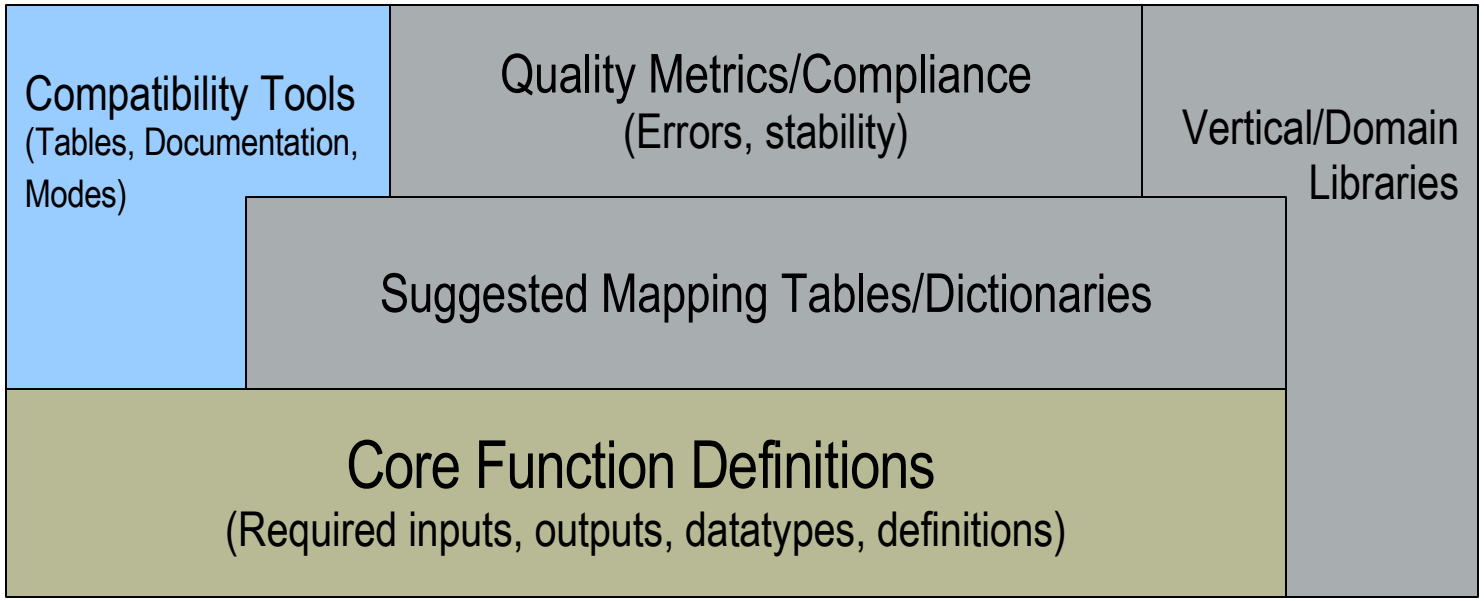
- The NMC is ***not*** standardizing on function ***Syntax*** (expression)
  - Users can still work with their syntax of choice and do not require wholesale rewriting or relearning new syntax
  - Vendors can still differentiate their products without the need of a common syntax

What are the functions NMC is standardizing ?

- Initial scope limited to “core” functions that are used commonly across applications
- 14 function classes with over 250 core functions
  - APPROXIMATION
  - BOOLEAN
  - COMPARISON
  - ELEMENTARY
  - LINEAR ALGEBRA
  - MATH CONSTANTS
  - MATRIX GENERATION
  - MATRIX OPERATORS
  - MEMBERSHIP
  - POLYNOMIALS
  - SET OPERATORS
  - SPECIAL FUNCTIONS
  - STATISTICS
  - VECTOR ANALYSIS

Consortium Technical Roadmap





Benefits of a Numeric Math Standard

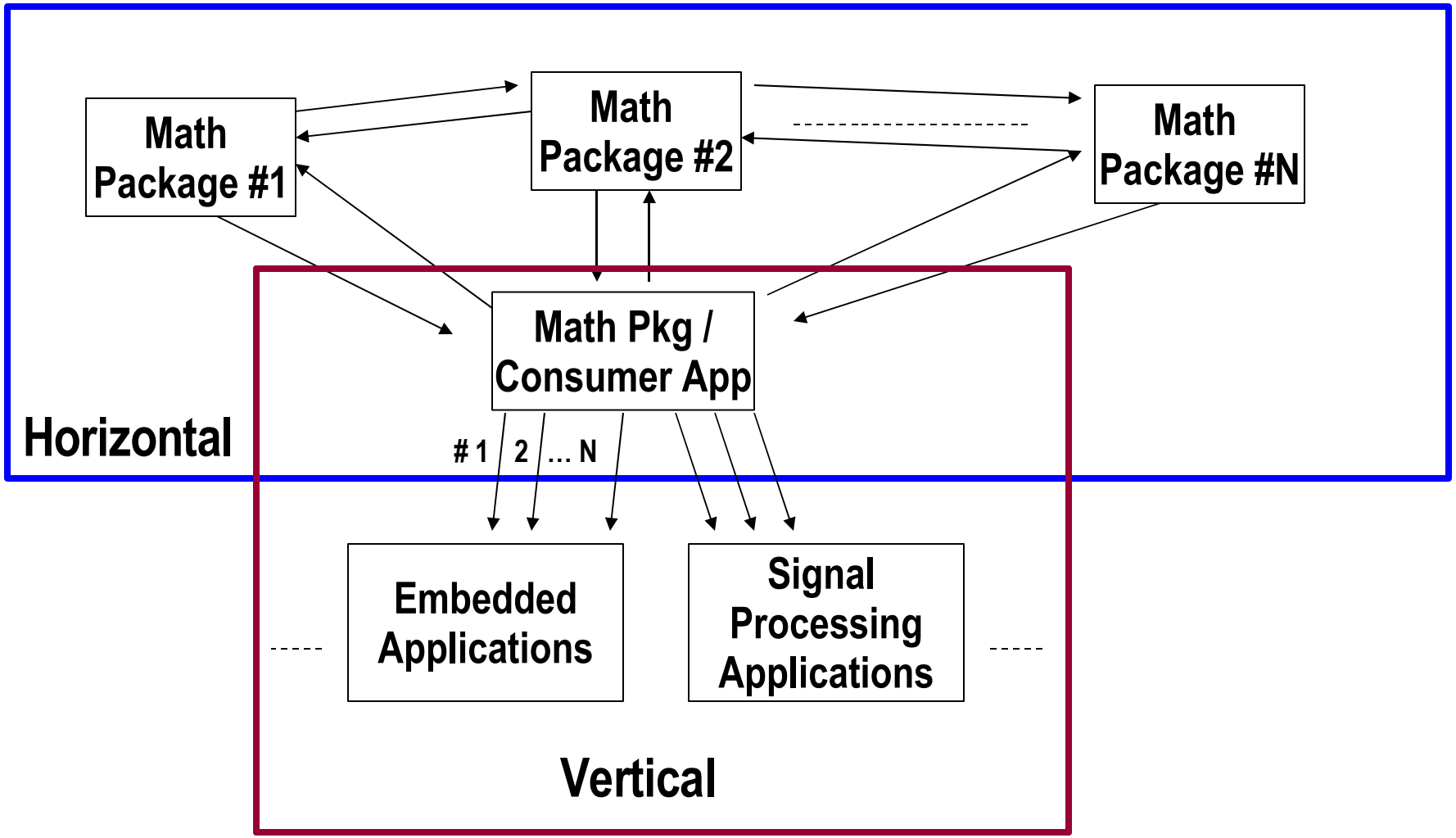
Vendors

- Easy entrance to their platform
- Can differentiate based on their core competency (performance, efficiency, visualization, symbolics, etc)
- NMC core “standard” function set will be stable and broadly accepted
- Can provide interfaces to other packages more efficiently

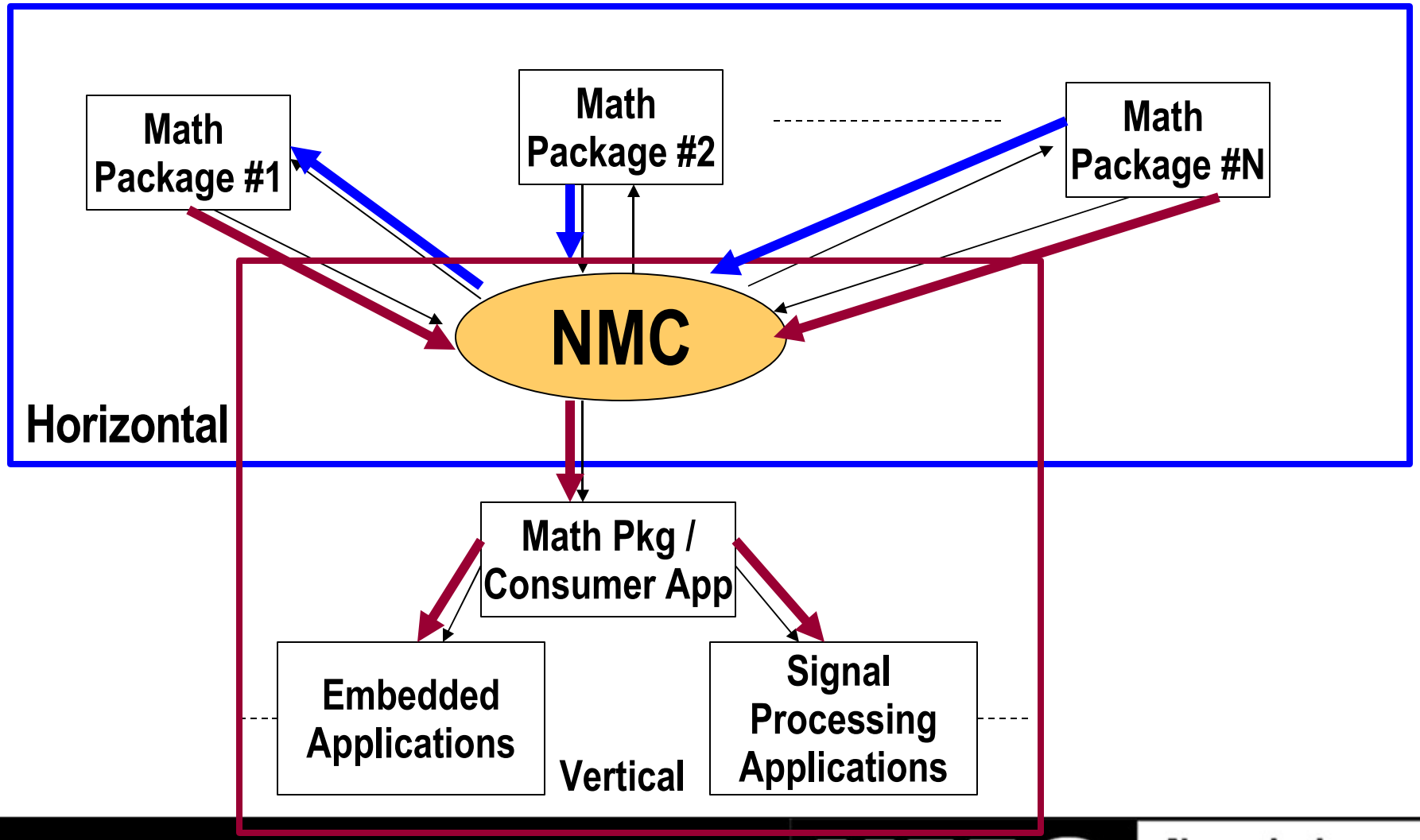
Users & Consumers

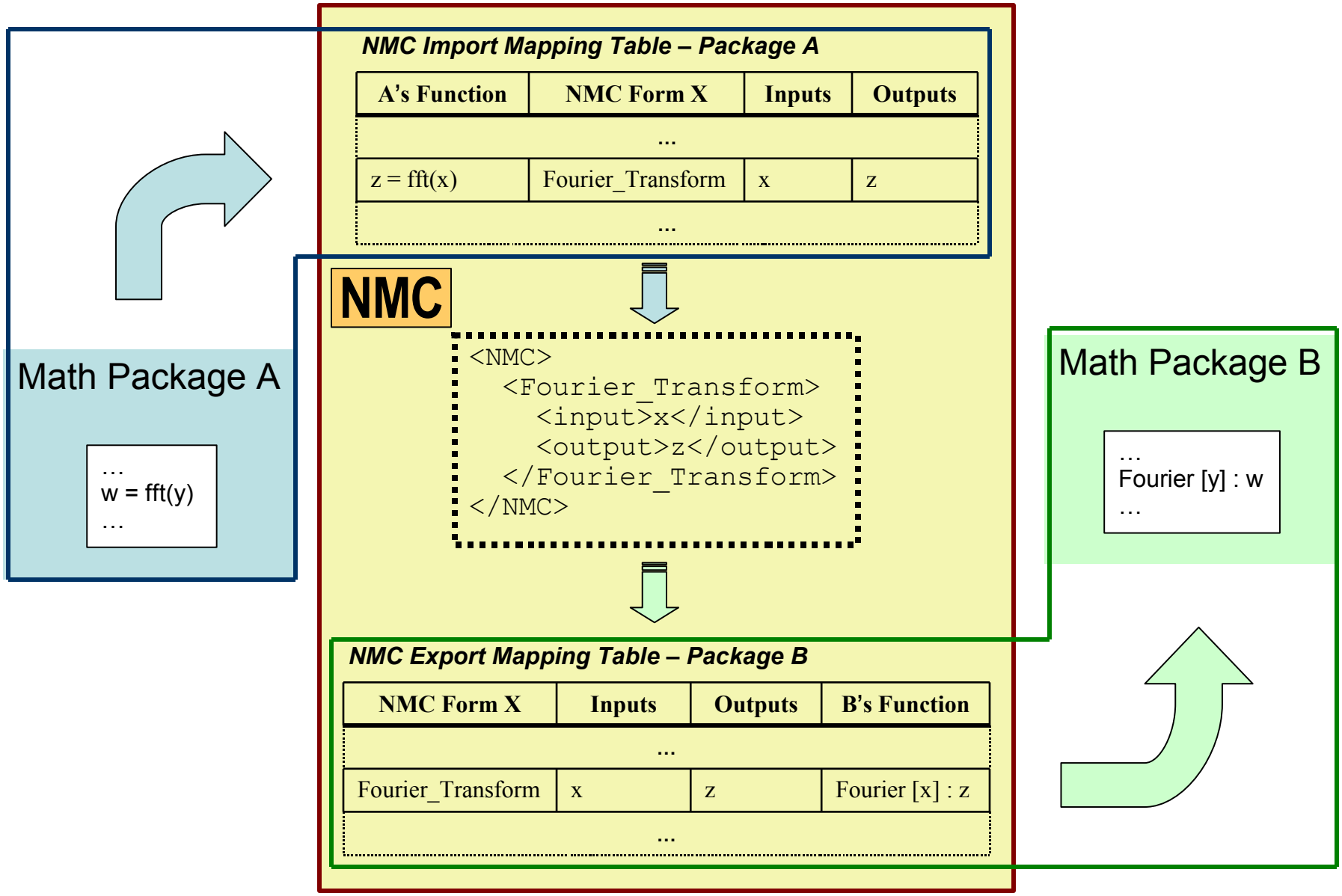
- Easy interchangeability of numerical math algorithms across providers
- Consumers of numeric math such as embedded deployment environments, simulation environments, etc. will have a common starting point

Horizontal & Vertical Usage - Current Situation



Horizontal & Vertical Usage - with NMC




NMC Import Mapping Table – Package A
A's Function
NMC Form X
Inputs
Outputs
...
z = fft(x)
Fourier_Transform
x
z
...
NMC
<NMC>
<Fourier_Transform>
<input>x</input>
<output>z</output>
</Fourier_Transform>
</NMC>
Math Package A
…
w = fft(y)
…
Math Package B
…
Fourier [y] : w
…
NMC Export Mapping Table – Package B
NMC Form X
Inputs
Outputs
B's Function
...
Fourier_Transform
x
z
Fourier [x] : z
...

Other Math-related Standards & NMC

- LAPACK/BLAS – linear algebra
- MathML – presentation & content math
- OpenMath – content math
- Other related standards - IEEE / ISO

NMC expects to:

- **Fully leverage LAPACK/BLAS in the Linear Algebra function class**
- **Complement Content MathML, OpenMath, and other standards, by focusing on numeric functions standardization**

NMC Launch Highlights

- NMC founding members at launch
  - INRIA/Scilab, Maplesoft, Mathsoft, National Instruments
- Launch of NMC on Aug.9, 2005
  - Business Wire Press Release by NMC
  - Website: www.nmconsortium.org
  - NMC Charter document
  - Testimonials from users - ArvinMeritor & UT Austin, and member companies
  - Follow up on targeted media list distributed across members
  - NI Week NMC presentation by Maplesoft, Mathsoft, and National Instruments
  - European re-release of info. & follow up in Sept 2005 led by INRIA/Scilab

NMC Numerical Mathematics Consortium

www.nmconsortium.org

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Executive Summary

Algorithms – The Backbone of Technical Professionals

Numerical algorithms form the backbone of many technical pursuits. From advanced research projects to industrial applications, algorithms provide the brains to problem-solving engines. Many engineers, scientists, and researchers spend months, years, even entire careers developing and honing algorithms in efforts to provide breakthrough innovation or create a better world around us.

It is this huge investment in intellectual property that the Numerical Mathematics Consortium (NMC) seeks to preserve by standardizing on a core set of mathematical functions applicable to numerical algorithms. With so much value placed in numerical algorithms, it is critical to allow the work of these technical professionals to be maintained across platforms, tools, and environments, without spending a significant amount of valuable time in "porting" or re-developing them.

Standards – A Must for Portability and Compatibility

Latest News

8/9/2005
Numerical Mathematics Consortium Proposes Open Standard for Algorithm Development

NMC Numerical Mathematics Consortium

NMC Future Plans

- Expand Recruitment
  - Broader recruitment of math related companies
  - Vertical consumers of numerical math
  - Organizations with numerical math focus
- Focus on Technical Specification
  - Monthly engagement at a technical level with current members
  - Agree on function classes & functions list (Dec. 2005, draft done)
  - Agree on standard semantic representation of functions
  - Publish preliminary technical specification with function definitions (Fall, 2006)
  - Focus on future areas

National Instruments' Perspective

Why is NI Interested in the NMC ?

- Many of our users want to combine I/O with algorithms built in external math tools
  - Numerous different options for integrating external math formulas on the diagram
- NI targets user diagrams to real-time OSes, embedded processors, and FPGAs
  - Need a standard for working with user algorithms
- We want LabVIEW and Xmath algorithms to be open for use in other environments

Math in LabVIEW

- Script Node plug-ins for Textual Math
  - Xmath - Maple -INRIA/Scilab
  - MATLAB - IDL
- ActiveX Connectivity
  - Mathcad - Mathematica -Excel
- Built-in Options
  - Graphical (VI) Libraries
  - MathScript Node (Textual, m-file script syntax)
  - Formula Node (Textual, C-like syntax)

NI Expected Benefits from the NMC

- Our focus is on supporting NMC standardization efforts with all our products to
  - Reduce our development effort in supporting external math but with more robust solution
  - Empower LabVIEW user diagrams (using external math leveraging the NMC) to run on multiple targets
  - Work with the vertical math consumer community to streamline the algorithm to embedded target development process

Maplesoft's Perspective

Why are we interested in the NMC ?

- Being open is a corporate philosophy
- Instrumental in a large number of existing standards, like MathML and OpenMath
- Extensive use of open standards throughout product line
- Maple is solidifying its position in the engineering toolchain; interoperability is key

Math in Maple today

- Very broad and deep set of mathematical algorithms
- Easy to use interactive user interface
- Connectivity to a large number of 3rd party systems (LabVIEW, MATLAB, Excel, C, Fortran, Java, Visual Basic, ...)

Expected benefits for Maplesoft

- Make strong math engine accessible to a wider audience (e.g. LabVIEW Toolbox)
- Leverage existing mathematical algorithms (vs. invent your own)
- Broaden Maple community by engaging anybody with a need for mathematical algorithms

Mathsoft's Perspective

Why is Mathsoft Interested in the NMC ?

- As we become more of an Enterprise Solution Provider our integrations with partner applications are increasingly important and frequently done
  - Currently, custom code is necessary for each integration and interface
  - The key benefit of an integrated solution with our partners is the sharing and passing of calculations, algorithms and results between the applications
  - We need a standardized, repeatable, known way for us to integrate to partner applications and for our partners to integrate to us

Mathsoft Expected Benefits from the NMC

- Engineers and Scientists will learn standardized algorithms that can be applied across jobs, education, and applications
  - This facilitates the ease with which resources can leverage their skills and knowledge – independent of the mathematical applications they are using

- Port code between applications – third party libraries will be developed, exposing custom or organizational standard algorithms
  - This will enable access and use from, and between, a variety of vendor's tools
  - Facilitate collaboration between organizations, departments, projects.

Summary

NMC Numerical Mathematics Consortium

- Open Standard for Algorithm Development
- Standardize Semantics
  - Define function behavior and parameters (number, order, and meaning)
- Benefits include
  - Portability, consistency, and usability
  - Promotes algorithm reuse
  - 250+ core math functions initially
  - Synchronization with existing standards

Reduces the overall cost of numerical algorithm development in different disciplines.

NMC Numerical Mathematics Consortium

For more information

- http://www.nmconsortium.org