MathML in IAMC Prototype

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1. IAMC Overview

- IAMC: Internet Accessible Mathematical Computation
- Goal: to make all kinds of mathematical computation easily accessible over the Web and the Internet
- Previous Activities:
  - An IAMC Workshop in ACM ISSAC 99 (International Symposium on Symbolic and Algebraic Computation)
  - Workshop on The Future of Mathematical Communication (FMC Dec. 1999)

- IAMC Architecture

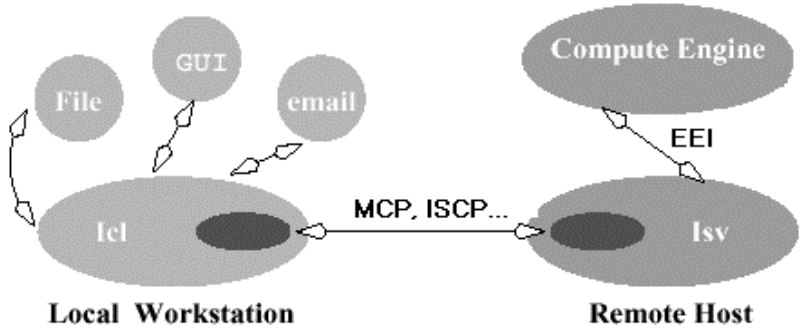
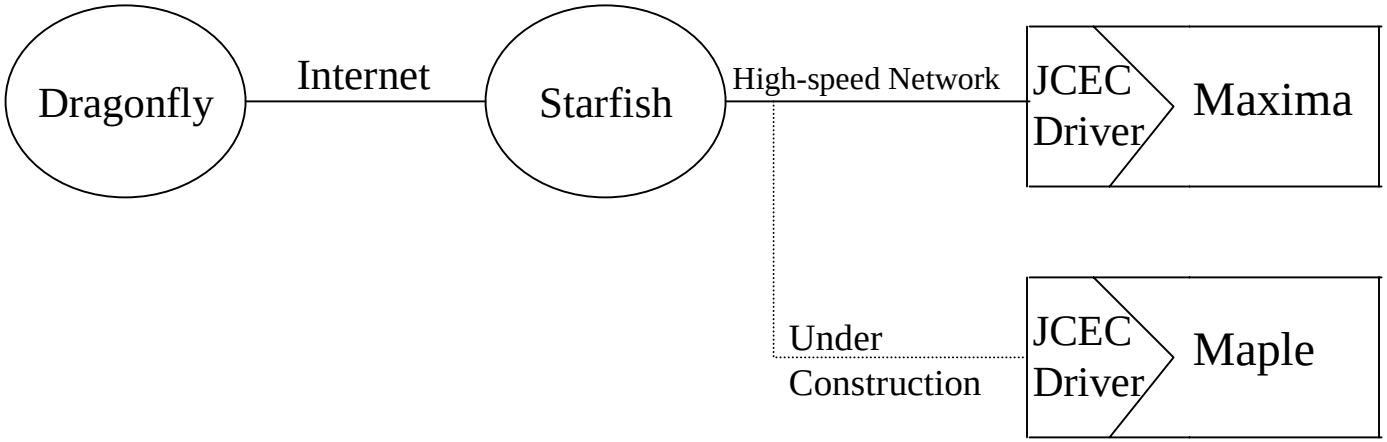


Figure 1: IAMC Architecture

IAMC is a distributed system to make mathematical computing easily accessible and usable on the Internet.

2. IAMC Prototype Structure



IAMC Client IAMC Server Computing Power Source

JCEC: Java Compute Engine Connectivity. An EEI specification in Java environment.

3. MathML: Official Language in IAMC

Adopting MathML as official language speaking in IAMC environment facilitates the development of IAMC prototype.

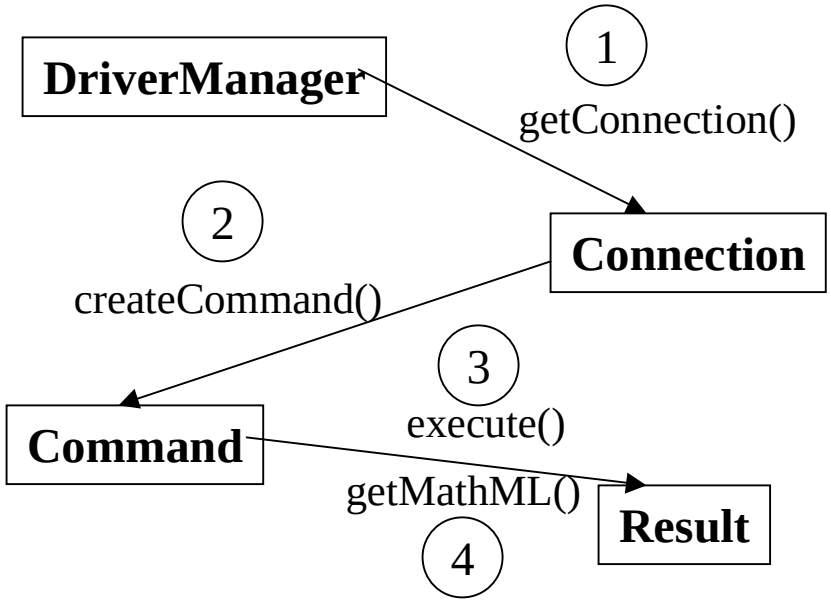
- Starfish can talk to compute engines in MathML
  - there are more and more engines can understand MathML;
  - if unfortunately a compute engine cannot, the EEI driver will be the translator.

- Mathematical expression rendering in Dragonfly becomes easier with MathML rendering packages such as WebEQ.

3.1 MathML Between Starfish and Compute Engines

How starfish connects compute engines for computational services? The answer is JCEC, Java Compute Engine Connectivity.

MathML is embedded in JCEC Java Library.



Sample Code

```
1. connection = DriverManager.getConnect(engine-uri, null, null);
2. command = connection.createCommand();
3. command.execute(MATHML, "….");
                              //deliver MathML content code
4. result = command.getResult();
   String mathmlstr1 =  result.getMathMLContent();
   String mathmlstr2 = result.getMathMLPresentation();
```

3.2 MathML Between Dragonfly and Starfish

Facts:

- *Dragonfly talks with Starfish in MCP: Mathematical Computation Protocol.*
- *MathML is one of the several key content encoding MCP supports.*
- *If MathML format is used, Dragonfly delivers computational requests in MathML Content Encoding formats.*
- *Dragonfly can ask results in either MathML content encoding (for further computation) or presentation encoding (for easy rendering).*

Sample MCP Message (Request):

Request Computation C3
Method: commandString
Send-result: yes
Content-type: text/mathml-content
Content-Length:

```
<math>
<apply>
   <fn>FACTOR</fn>
   <apply>
      <plus/><cn type="integer">-1</cn>
      <apply>
         <times/><cn type="integer">4</cn>
         <apply>
            <power/><ci>X</ci><cn type="integer">2</cn>
         </apply>
      </apply>
   </apply>
</apply>
</math>
```

factor(4*x^2-1)

Sample MCP Message (Response):

Response Computation C3
Content-type: text/mathml-content-presentation
Content-Length:

```
<math><apply><times/><apply><plus/>
<apply><times/><cn type="integer">2</cn><ci>X</ci>
</apply><apply><minus/><cn type="integer">1</cn>
</apply></apply><apply><plus/><apply>
<times/><cn type="integer">2</cn><ci>X</ci>
</apply><cn type="integer">1</cn></apply>
</apply></math>

<math><mrow><mrow><mo>(</mo><mrow>
<mrow><mn>2</mn><mo>&InvisibleTimes;</mo><mi>X</mi>
</mrow><mo>-</mo><mn>1</mn></mrow><mo>)</mo></mrow>
<mo>&InvisibleTimes;</mo><mrow><mo>(</mo><mrow>
<mrow><mn>2</mn><mo>&InvisibleTimes;</mo><mi>X</mi>
</mrow><mo>+</mo><mn>1</mn></mrow><mo>)</mo>
</mrow></mrow>
</math>
```

(2*x+1) * (2*x-1)

4. MathML/Graph: Extending MathML for Graph Encoding

Problem:
IAMC wants to have mathematical graph functionality that is supported by most compute engines, which means a graph encoding format is required.

Solution 1:
How about gif/jpeg/png?

It is feasible solution but the graphics cannot to be further manipulated in client side.

Solution 2:
The server returns some data that can be easily drawn. An example is the coordinate info.

How to encode the coordinate data?

- Ad hoc method
- MathML/Graph: an XML implementation

4.1 Ad-hoc Method

2-dimensional:

```
100                      %% take 100 samples in X axis
1.000      2.3456        %%  100 (x,y) coordinates follow
….
```

3-dimensional:

```
30         40            %% 30 samples in X axis, and 40 samples
                            in Y axis
1.0   2.3456   3.1209    %%  30*40=1200 (x,y,z) coordinates
                            follow
….
```

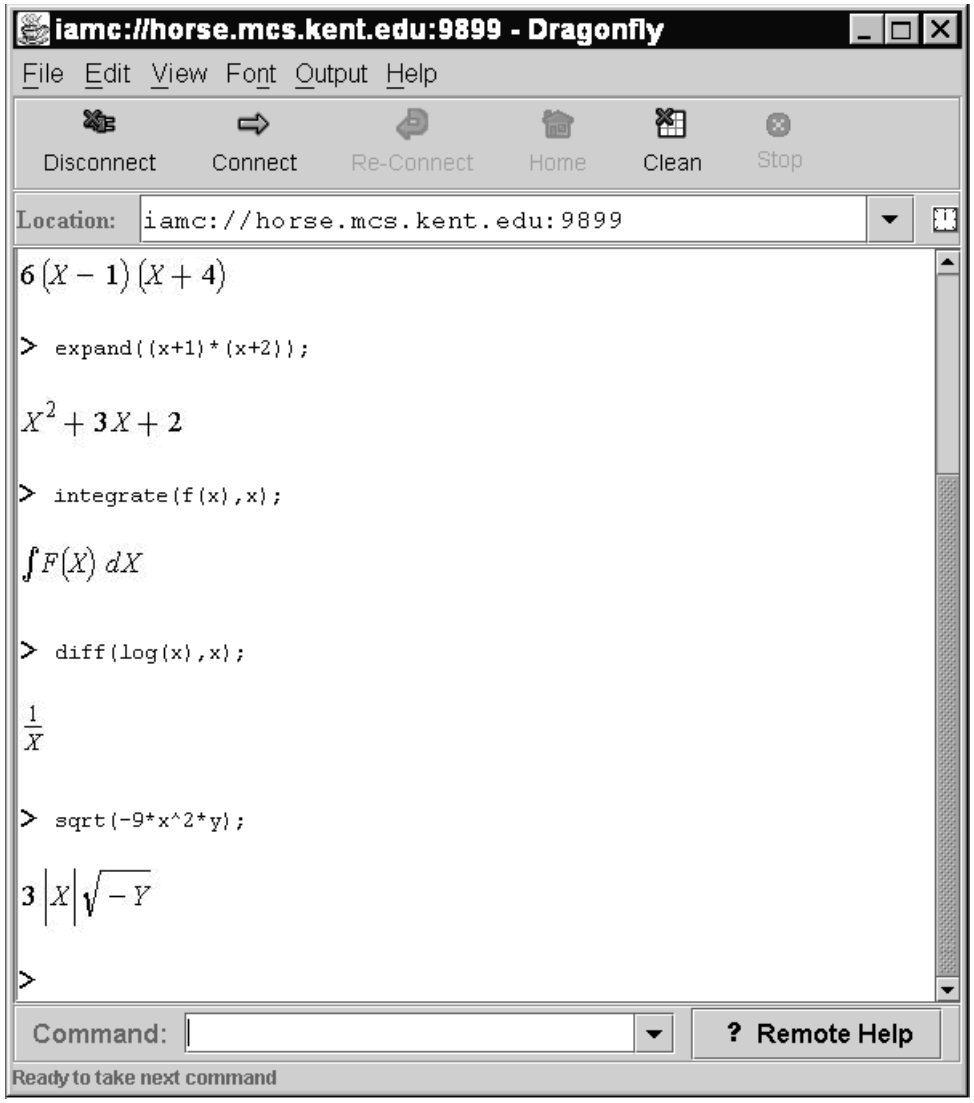
4.2. MathML/Graph Format

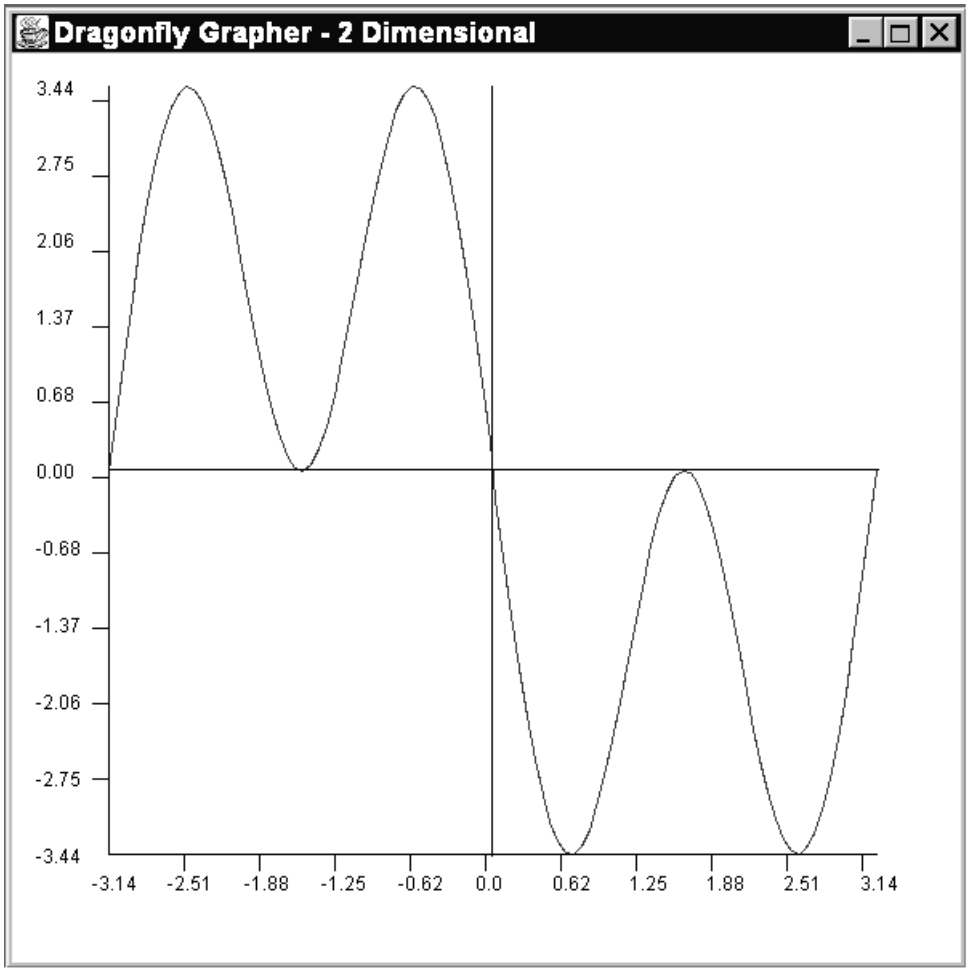
```
<math-graph>
        <title>Unit Circle</title>
        <dimension>2</dimension>
        <xpoints>100</xpoints>
        <lower>0</lower>
        <upper>1.0</upper>
        <coordinates>
        -3.1415926535897931    -1.0305047481203616E-15,
        -3.0781261353354537    -0.5319297654044477,
        -3.0146596170811146    -1.0511760911187285,
        ...
        </coordinates>
</math-graph>
```

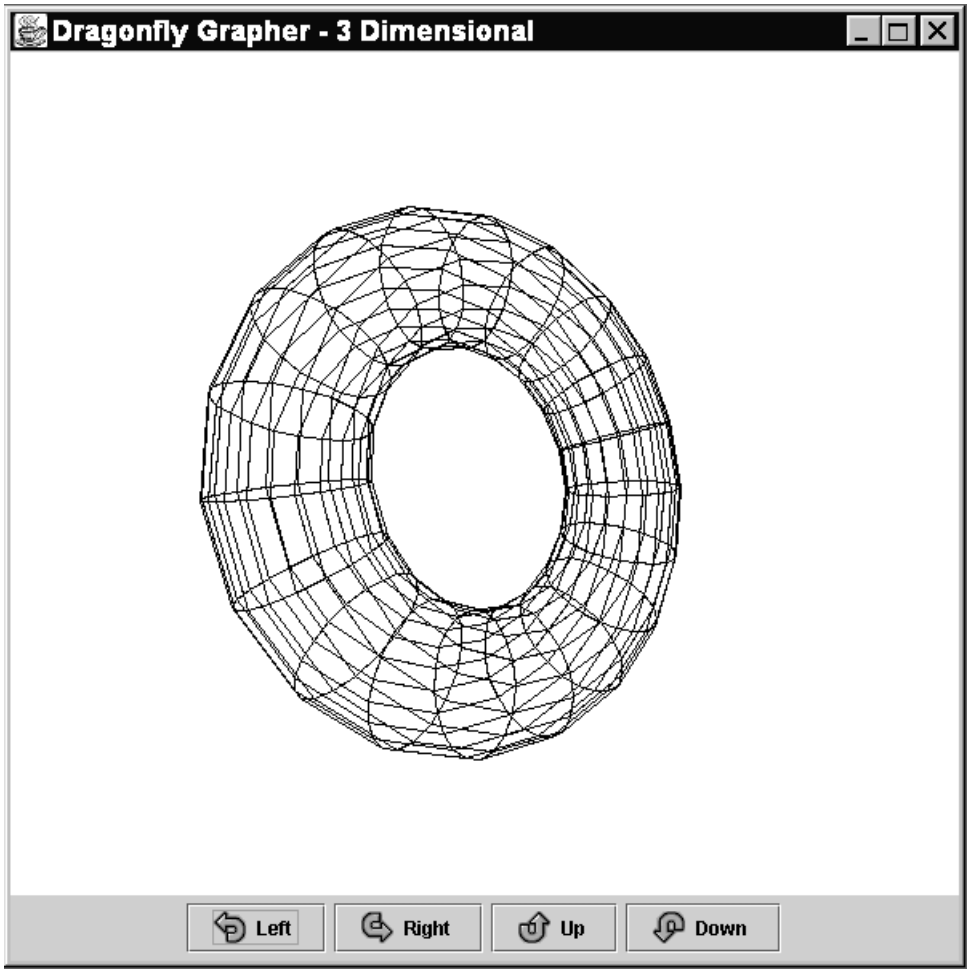
```
<math-graph>
        <title>Torus</title>
        <dimension>3</dimension>
        <xpoints>30</xpoints>
        <ypoints>40</ypoints>
        <coordinates>
        -2.0        -2.0                0.0
        -2.0        -1.8620689655       0.137931034

        ...
        </coordinates>
</math-graph>
```

5. Demo Captures

- Main Dragonfly Workspace
- 2-Dimensional Grapher
- 3-Dimensional Grapher


iamc://horse.mcs.kent.edu:9899 - Dragonfly
File Edit View Font Output Help
Disconnect
Connect
Re-Connect
Home
Clean
Stop
Location: iamc://horse.mcs.kent.edu:9899
$6(X-1)(X+4)$
> expand((x+1)*(x+2));
X^2+3X+2
> integrate(f(x),x);
$\int F(X)\,dX$
> diff(log(x),x);
$\frac{1}{X}$
> sqrt(-9*x^2*y);
$3\left|X\right|\sqrt{-Y}$
>
Command:
? Remote Help
Ready to take next command


Dragonfly Grapher - 2 Dimensional
3.44
2.75
2.06
1.37
0.68
0.00
-0.68
-1.37
-2.06
-2.75
-3.44
-3.14
-2.51
-1.88
-1.25
-0.62
0.0
0.62
1.25
1.88
2.51
3.14


Dragonfly Grapher - 3 Dimensional
Left
Right
Up
Down

6. Further Information

- The Online Proceeding of the IAMC'99 Workshop
  - http://horse.mcs.kent.edu/icm/research/iamc99proceedings
- The IAMC homepage
  - http://horse.mcs.kent.edu/icm/research/iamc
- The Workshop on The Future of Mathematical Computation
  - http://www.msri.org/activities/events/9900/fmc99