Mathematical Document Authoring With xfy

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Abstract

xfy is a run-time platform for creating, editing and browsing compound XML documents. It is capable of handling multiple XML vocabularies on a WYSIWYG-style workspace. Furthermore, it has an extensible architecture to manage additional standard or private XML vocabularies, namely plug-ins and XVCD. In xfy, we developed an editor plug-in, to edit the MathML presentation markup, and a 2D/3D plot plug-in, to view algebraic functions graphically. The XVCD architecture can integrate these plug-ins to provide a plot tool to draw algebraic functions. As a result, the plot tool is interactive, meaning the algebraic function curves are updated immediately when edited by the MathML editor. We then used these plug-ins to construct interactive XML content for use in mathematics education.

1 Introduction

In this paper, we will show that we've created a platform to edit and view mathematical documents which are expressed purely in XML format.

For this purpose, we use Justsystems Corporation's xfy software [2], which is a tool for authoring XML data in a workspace. xfy has an extensible architecture to manage standard or private XML vocabularies, namely plug-ins and XVCD. xfy also can handle compound XML documents in a straightforward manner. Compared with other authoring tools for compound XML documents such as Amaya [1], a significant feature of xfy is XVCD [2], which is an extension of XSLT and a script language for translating and editing XML documents. XVCD provides a user-defined view for XML documents in xfy.

Currently, xfy does not fully support mathematical documents. To solve this, we created a new editor plug-in for editing MathML presentation markup [3] and a new browser plug-in for viewing plotXML, a private XML for plotting algebraic curves in xfy.

To edit plotXML, we used XVCD. It produces an editing environment for expression elements in plotXML. The editing tool for plotXML has an interactive feature, meaning that the curves of algebraic functions are updated immediately when the algebraic functions are edited in the MathML editor. We can then apply these new plug-ins to construct interactive XML content that can be used to create tools for teaching mathematics.

Related works can be seen online. We referred to Java applets to explain mathematics interactively (e.g. [7]). We can show that similar content supporting the same feature are achieved by compound XML and XVCD.

2 xfy

xfy enables us to handle compound XML vocabularies, such as MathML, SVG, and so on, inside a workspace. Furthermore, to manage any type of XML vocabulary it has extensible architectures called plug-in and XVCD.

A significant feature of xfy is Vocabulary Connection (VC) technology. VC connects source XML (e.g. private XML) to a different destination XML (e.g. XHTML). To apply VC to XML documents, the scripting language called XVCD is available. XVCD itself is written in XML.

The destination XML is then viewed by the appropriate plug-in. The plug-in is developed in Java and applied to the corresponding namespace. If the destination XML is a compound XML, the appropriate plug-ins are applied to view the compound XML on the same screen.

Fig.1 shows an example for handling a compound XML (in this case, XHTML and SVG together in a document). First, xfy creates a DOM tree for the document. Then, depending contents in the namespaces, the XHTML zone and the SVG zone in the DOM tree are processed by the XHTML plug-in and the SVG plug-in, respectively. xfy then merges their results and gives us an image of the XML document.

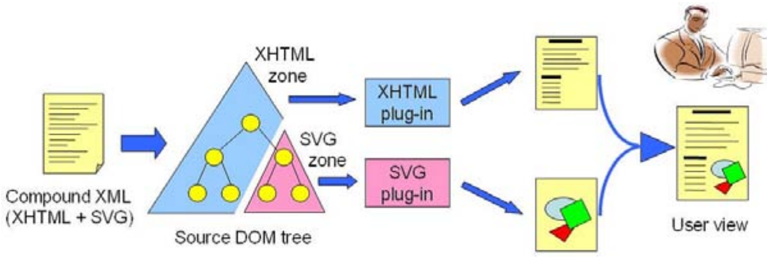


Fig.1 XML handling flow in xfy

2.1 Plug-ins

The xfy plug-ins are adaptive, modular, and vocabulary specific authoring engines for representative standard or private XML vocabularies. Each plug-in corresponds to a different namespace that specifies which one will be applied to the XML vocabulary (Fig.2). The xfy plug-ins are developed in Java and perform the DOM tree manipulation (display and edit) through the xfy API. The xfy API structure is currently not open to the public, but it soon will be.

2.2 XVCD

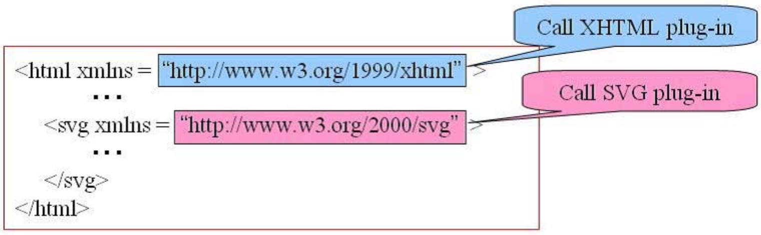
XVCD is a script language for translating and editing XML documents. The translation works as following:

1. xfy holds the DOM tree for the XML document, called the ”source” DOM tree.

2. Through XVCD translation, xfy obtains a new DOM tree, this is called the ”destination” DOM tree.

3. The destination DOM tree is then displayed by the xfy plug-ins.

As a result, users are able to view the entire XML document. If the user makes a change to the destination DOM tree, then XVCD updates the source DOM tree immediately. Thus, XVCD gives a user-dependent view and a dynamic editing platform for XML documents (Fig.3).



```
<html xmlns = “http://www.w3.org/1999/xhtml” >
    ...
   <svg xmlns = “http://www.w3.org/2000/svg” >
    ...
   </svg>
</html>
```

Fig.2 Namespace and plug-in

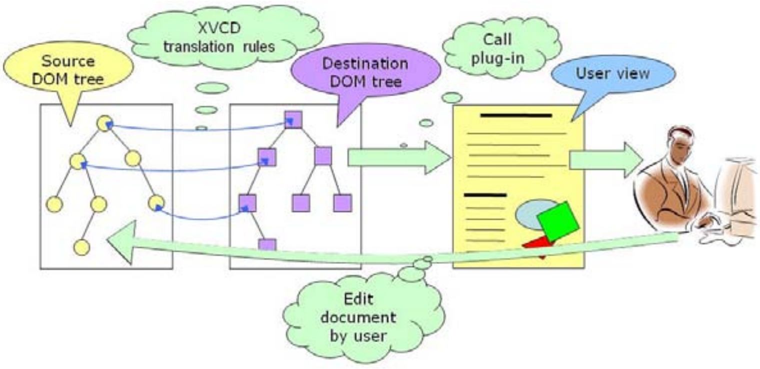


Fig.3 XVCD translation flow

3 Math authoring plug-ins

In xfy, we developed a MathML editor plug-in to edit the MathML presentation markup and a 2D/3D plot plug-in to view algebraic functions.

Since we wish to design a direct-manipulation editor with uniform editing behavior, we referred to Padovani and Solmi [6] to develop our new MathML editor for xfy. They proposed seven features for direct-manipulation editors. How features are satisfied for our MathML editor are summarized as following:

Edit Points The MathML editor has this feature, because the caret is supported by the xfy API.

Slots The DOM tree is updated while editing MathML in xfy. Thus, missing parts in MathML are identifiable and easily reachable in the MathML editor.

Geometric Navigation Since the default editing mode of the MathML editor is consistent with the WYSIWYG principle, the MathML editor has this feature.

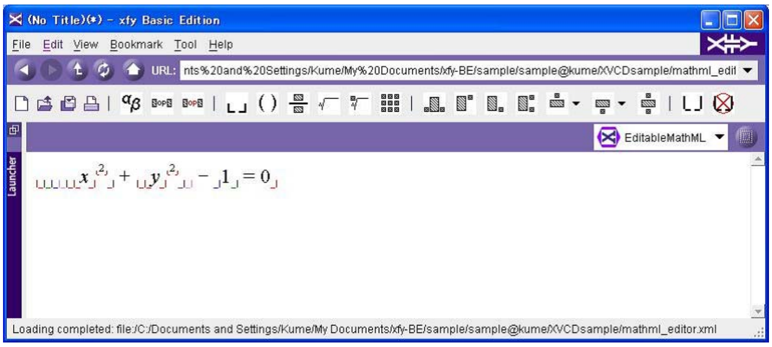
Content Navigation Because xfy has the DOM tree of MathML, it is possible to provide this navigation mode which is based on higher granularity such as subexpression. This will be implemented, but currently not yet.

Model Navigation Users can view a structured outline of the edited documents while editing MathML. But xfy does not provide editing functionalities for the structured outline because the structure of XML might be broken by users. Thus the MathML editor satisfies weakly this navigation mode.

Selection The MathML editor has this feature, i.e. it is possible to select parts of the edited document that have no semantic meaning.

Editing This feature means that "Depending on the application and on the model structure, the range of editing operations available at one specific edit point may vary significantly". Currently the MathML editor does not have this feature.

Thus, presently, features such as Edit Points, Slots, Geometric Navigation, Model Navigation, and Selection are implemented. Fig.4 shows a typical screenshot taken while editing an expression.



URL: nts%20and%20Settings/Kume/My%20Documents/xfy-BE/sample/sample@kume/XVCDsample/mathml_edit

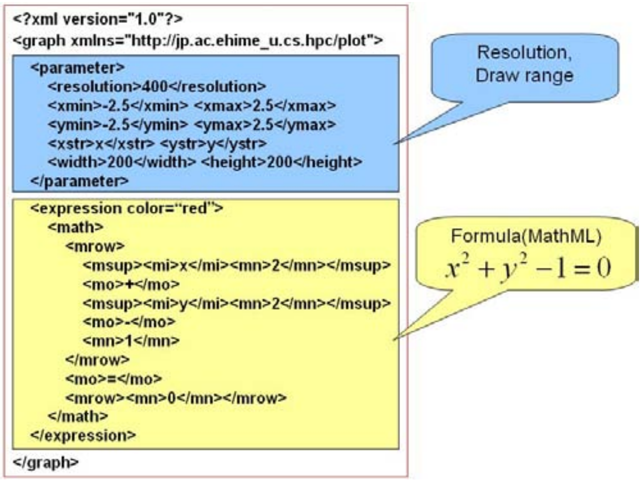
$x^2 + y^2 - 1 = 0$

Loading completed: file:/C:/Documents and Settings/Kume/My Documents/xfy-BE/sample/sample@kume/XVCDsample/mathml_editor.xml

Fig.4 The MathML editor in xfy

For the plot plug-in, we defined a private XML vocabulary, called plotXML, to draw algebraic functions. plotXML does not have a well-defined DTD and schema. However, since it is a XML vocabulary, we created a namespace and a tagset for it, which are defined in a Java class PlotXMLZoneImpl.java.

In plotXML, there are three main XML elements: draw range, resolution and formula. The draw range (`<xmin>`, `<xmax>`, `<ymin>`, `<ymax>`) shows plot ranges , and the resolution (`<resolution>`) specifies the number of points to draw algebraic curves in the draw ranges. The formula element (`<expression>`) is written in the MathML presentation markup. It is checked whether the formula has syntactically and semantically correct input to draw or not. Further, an optional element (`<drawobject>`) can be used to draw points, lines, regions and so on. For example, the plotXML for the equation $x^2 + y^2 - 1 = 0$ can be expressed in Fig.5 and its corresponding view in xfy is in Fig.6.

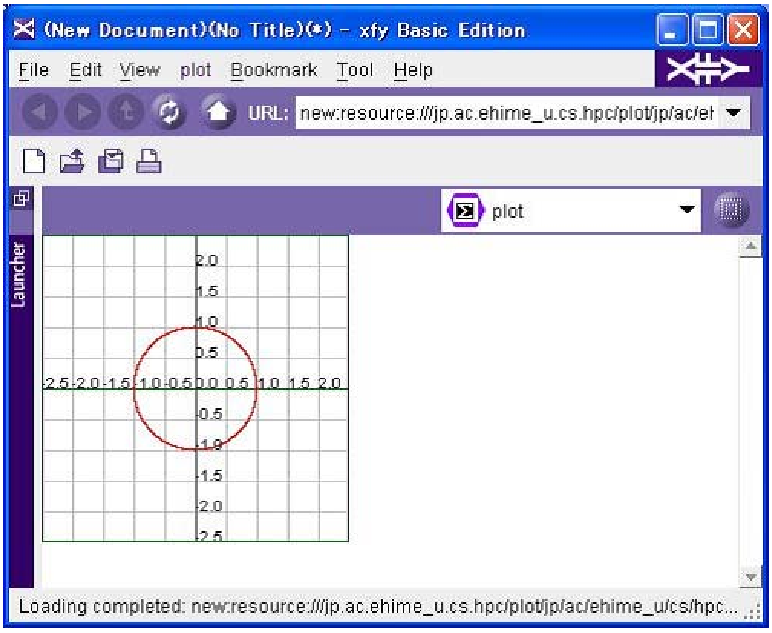


```
<?xml version="1.0"?>
<graph xmlns="http://jp.ac.ehime_u.cs.hpc/plot">
  <parameter>
    <resolution>400</resolution>
    <xmin>-2.5</xmin> <xmax>2.5</xmax>
    <ymin>-2.5</ymin> <ymax>2.5</ymax>
    <xstr>x</xstr> <ystr>y</ystr>
    <width>200</width> <height>200</height>
  </parameter>
  <expression color="red">
    <math>
      <mrow>
        <msup><mi>x</mi><mn>2</mn></msup>
        <mo>+</mo>
        <msup><mi>y</mi><mn>2</mn></msup>
        <mo>-</mo>
        <mn>1</mn>
      </mrow>
      <mo>=</mo>
      <mrow><mn>0</mn></mrow>
    </math>
  </expression>
</graph>
```

Resolution, Draw range

Formula(MathML) $x^2 + y^2 - 1 = 0$

Fig.5 The plotXML source code



Loading completed: new:resource:///jp.ac.ehime_u.cs.hpc/plot/jp/ac/ehime_u/cs/hpc...

Fig.6 The plotXML plug-in output

4 A plot tool in xfy

We developed a plot tool to draw curves of algebraic functions using these plug-ins and XVCD. This tool is interactive and updates the algebraic function curves when edited by the MathML editor plug-in. This is achieved by the following (Fig.7):

1. plotXML itself is copied to the destination DOM tree. xfy displays the plotXML by the plotXML plug-in.

2. The formulae contents in the plotXML are mirrored into a part of the destination DOM tree by XVCD. The MathML editor plug-in displays the formulae.

3. If the formulae are edited through the MathML plug-in, then the plotXML in the destination DOM tree is also updated by XVCD.

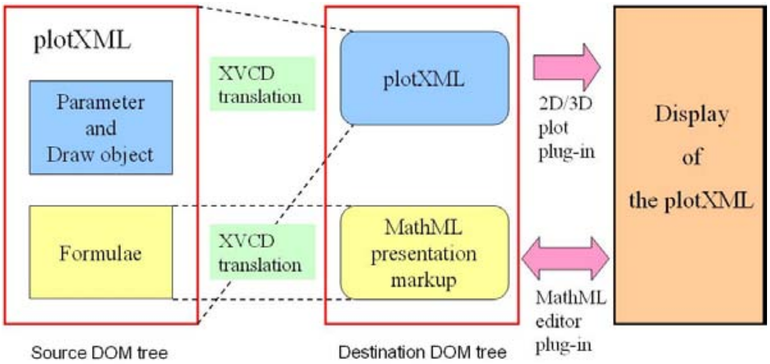
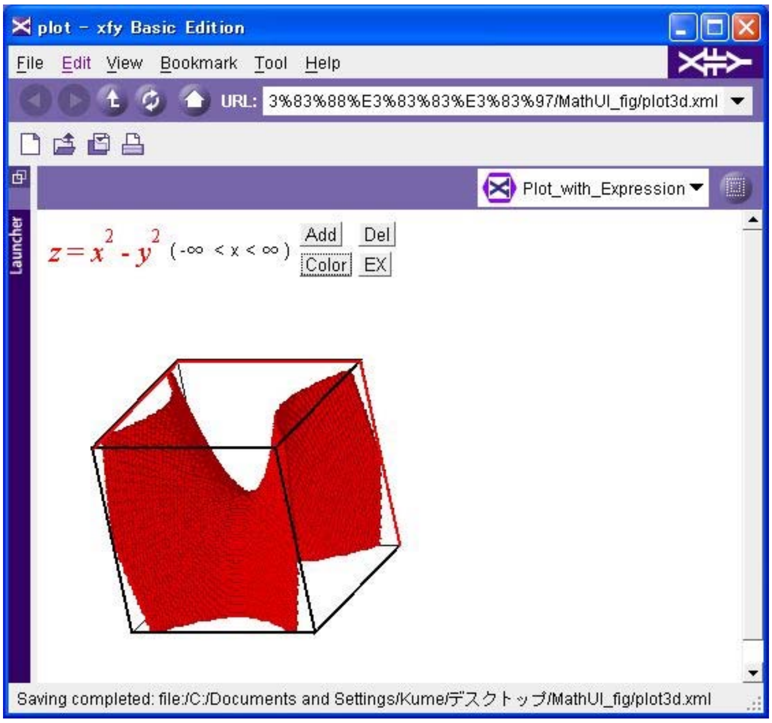


Fig.7 The plot tool flow

Fig.8 shows a screenshot of the plot tool using the MathML editor and the plotXML plug-ins.



URL: 3%83%88%E3%83%83%E3%83%97/MathUI_fig/plot3d.xml

$z = x^2 - y^2$ $(-\infty < x < \infty)$

Saving completed: file:/C:/Documents and Settings/Kume/デスクトップ/MathUI_fig/plot3d.xml

Fig.8 3D plot tool

This idea enabled us to make an interactive mathematics book, and we have developed several examples.

5 Applications for creating interactive content

We applied our plug-ins to construct interactive mathematics learning tools.

We researched online to find accessible and interactive Java applets for epsilon-delta calculus before we developed the documents in this section (e.g. [7]). We can show that similar content supporting the same feature are achieved by XML documents and XVCD in xfy.

We show two examples here, an elliptic curve and its points over the curve, and the epsilon-delta calculus.

In the former example, the curve and the points changed by the alternation of coefficients of the elliptic curve (Fig.9). In the latter example, we can see whether we can take a suitable value of delta depending on a certain value of epsilon in the plot (Fig.10).

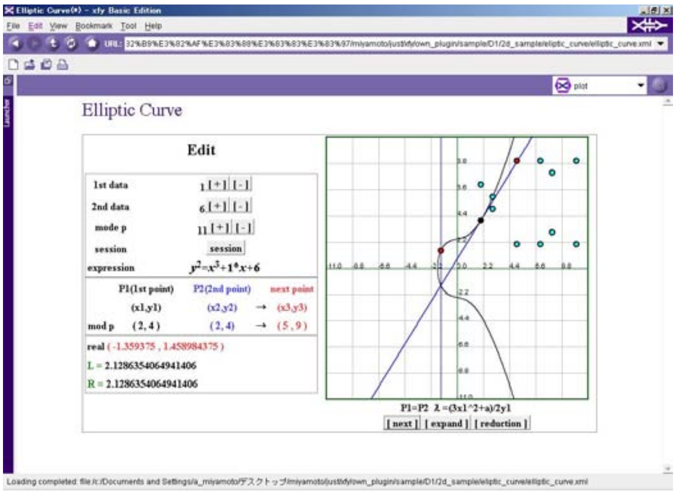
The documents presented here are constructed using compound XML and XVCD, which are written by expert users. The compound XML can be written in xfy, but XVCD is programmed on a generic XML editor.

The compound XML has multiple XML vocabularies such as:

- Documents: XHTML
- Expressions: MathML presentation markup
- Figures: plotXML

Of course, we might use other XML supporting mathematical documents, such as OMDoc [4], MeML [5], and so on.

In both examples, the plot images are updated in real-time by changing the values in the document. This is a huge advantage of xfy.


Elliptic Curve(*) - xfy Basic Edition
File Edit View Bookmark Tool Help
URL: 32%B9%E3%82%AF%E3%83%88%E3%83%83%E3%83%97/miyamoto/justxfy/own_plugin/sample/D1/2d_sample/eliptic_curve/elliptic_curve.xml
plot
Launcher
[+] [-]
session
[next] [expand] [reduction]
11.0
8.8
6.6
4.4
2.2
0.0
2.2
4.4
6.6
8.8

Elliptic Curve

Edit

1st data	1
2nd data	6
mode p	11
session	session
expression	$y^2=x^3+1*x+6$

	P1(1st point)	P2(2nd point)		next point
	(x1,y1)	(x2,y2)	→	(x3,y3)
mod p	(2, 4)	(2, 4)	→	(5, 9)

real (-1.359375 , 1.458984375)

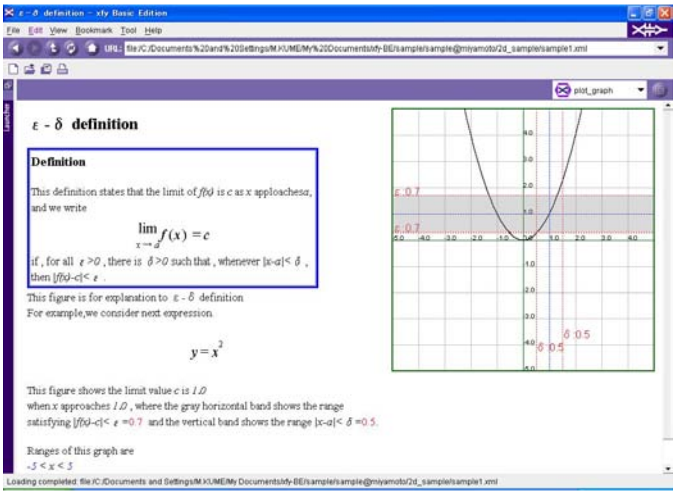
L = 2.1286354064941406

R = 2.1286354064941406

P1=P2 λ =(3x1^2+a)/2y1

Loading completed: file:/c:/Documents and Settings/a_miyamoto/デスクトップ/miyamoto/justxfy/own_plugin/sample/D1/2d_sample/eliptic_curve/elliptic_curve.xml

Fig.9 Elliptic curve



ε - δ definition - xfy Basic Edition
File Edit View Bookmark Tool Help
URL: file:/C:/Documents%20and%20Settings/M.KUME/My%20Documents/xfy-BE/sample/sample@miyamoto/2d_sample/sample1.xml
plot_graph
Launcher
ε 0.7
ε 0.7
δ 0.5
δ 0.5

ε - δ definition

Definition

This definition states that the limit of *f(x)* is *c* as *x* apploachesa, and we write

$$\lim_{x \to a} f(x) = c$$

if , for all ε >0 , there is δ >0 such that , whenever |x-a|< δ , then |f(x)-c|< ε .

This figure is for explanation to ε - δ definition
For example,we consider next expression

$$y = x^2$$

This figure shows the limit value *c* is *1.0*
when *x* approaches *1.0* , where the gray horizontal band shows the range satisfying |f(x)-c|< ε =0.7 and the vertical band shows the range |x-a|< δ =0.5.

Ranges of this graph are
-5 < x < 5

Loading completed: file:/C:/Documents and Settings/M.KUME/My Documents/xfy-BE/sample/sample@miyamoto/2d_sample/sample1.xml

Fig.10 epsilon-delta calculus

6 Conclusions and Future Work

In this paper, we presented new plug-ins to edit the MathML presentation markup and plotXML for xfy. They provide us with an interactive feature for using mathematical documents. Future works include

- Developing the direct manipulation features of the MathML editor,
- Assessing the plug-ins' value in terms of usability,
- Evaluating the interactive mathematical doucments with real students.

References

[1] Amaya, `http://www.w3.org/Amaya/`

[2] xfy, `http://www.xfy.com/`

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[4] OMDoc, `http://www.mathweb.org/omdoc/`

[5] Paul S. Wang, Norbert Kajler, Yi Zhou, and Xiao Zou, WME: Towards a Web for Mathematics Education, Proceedings of the 2003 international symposium on Symbolic and algebraic computation, pp.258-265, 2003.

[6] Luca Padovani and Riccardo Solmi, An Investigation on the Dynamics of Direct-Manipulation Editors for Mathematics, Lecture Notes in Computer Science Vol.3119, pp.302-316, 2004

[7] Java Compornents for Mathematics,`http://math.hws.edu/javamath/`