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A web system for the 3D display of bivariate mathematical functions

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***Abstract*—A mathematical software package NUMPAC includes many routines for computing special functions of single or double variables. To view each special function in 2D or 3D graphics, we have constructed a system on the Web for displaying the figures of special functions of two variables. This system enables users to display special functions in 3D graphics dynamically as well as interactively.**

***Index Terms*—Online system, WWW, 3D dynamic display, special functions, mathematical software package**

I. Introduction

NUMPAC[1], [2] is a mathematical software package constructed at Nagoya University, which has been installed in a number of computers in Japanese universities since 1971 and has been used by a large number of users. NUMPAC consists of around 1000 subroutines written in FORTRAN with their manuals for performing various numerical computations, say, linear systems of equations, nonlinear equations, eigenvalue problems, interpolations, integrations, differential equations, special functions and so on.

In 1996, we started to develop NetNUMPAC[3], [6], [4], an online system on the WWW for the NUMPAC, which enables any users to search and browse the hypertext manuals as well as download subroutines. Further, NetNUMPAC provides users with facilities of running the test programs to demonstrate how the subroutines depicted on the manual pages work. On the other hand, NetNUMPAC provides novice user with a simple user-interface to compute with a software in the NUMPAC without writing a main program calling the software. An interface to get computed results in a graphical form is also available.

In this paper we describe one of the facilities of NetNUMPAC, namely, a facility to display computed results in 3D graphics, in particular, a dynamic and interactive display system on the Web for a variety of special functions such as Bessel functions and interpolations of bivariate functions or of two-dimensional data as well as for functions defined by users. No other systems seem to exist on the Web for computing mathematical functions like special functions and displaying them in 3D graphics dynamically and interactively.

II. NUMPAC

NUMPAC is a general-purpose numerical subroutine library constructed by the members of Numerical Analysis Group and Computer Center of Nagoya University since 1971. In Japan NUMPAC has been installed in more than fifty major public computing institutes including seven National University Computer Centers whereas in 1998 it was installed in Hitachi supercomputer SR2201 at the Polish-Japanese Institute of Computer Techniques in Warsaw, Poland.

NUMPAC covers a wide range of numerical computations as follows (the numerals in parentheses denote the numbers of members included): systems of linear equations (40), eigenvalue analysis (29), nonlinear equations (14), interpolations (25), Fourier analysis (34), numerical quadrature (38), ordinary differential equations (4), special functions (148) as well as semi-numerical processing (20) like sorting. We mean by the member in NUMPAC a small group of subroutines or subprograms; namely, each member consists of single and double precision versions at least and sometimes includes even complex value and quadruple precision versions, too. Furthermore, several principal linear algebra routines were selected to be rewritten for use on supercomputers. Afterwards, other routines were added to the group of supercomputer versions, until now NUMPAC has 19 members tuned for vector supercomputers manufactured by Fujitsu, Hitachi and NEC.

The richest part of NUMPAC programs is the field of special function (148). Indeed typical ones are Bessel functions of integer or real order and real or complex argument and their related integrals and zeros; inverse hyperbolic functions; Struve functions; Kelvin functions; exponential integrals; Gamma function of complex argument; incomplete Gamma functions; incomplete Beta function; Dawson's integral; Clausen's integral; integral of the complementary Error function; Riemann Zeta function; solutions of Thomas-Fermi equation and Blasius equation and their derivatives; Abramowitz functions; Langevin function; orthogonal polynomials and so on.

III. NetNUMPAC

The NetNUMPAC system, developed at University of Fukui, aims at making the NUMPAC routines and their manuals accessible to anyone who can access the WWW but doesn't want to use the mainframe computer, which accommodates the NUMPAC routines, in the computer centers of the principal Universities in Japan. Figure 1 shows the top page of NetNUMPAC.

The facilities provided by NetNUMPAC are as follows:

1) Retrieving the manual corresponding to such a routine as

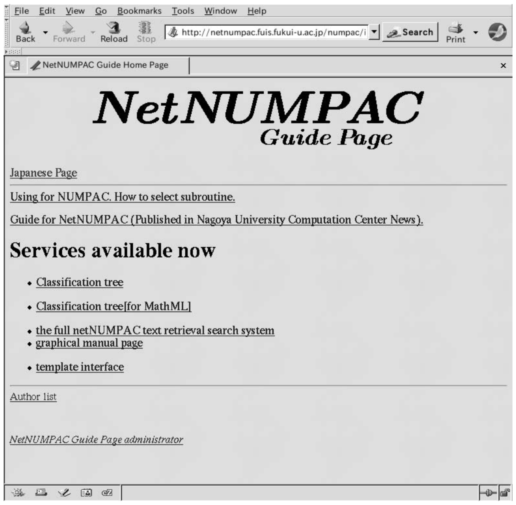

Fig. 1. Top page of the NetNUMPAC system

Fig. 2. Top class of NetNUMPAC and subclasses

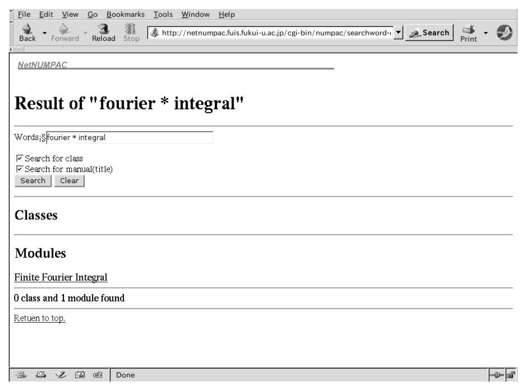

Fig. 3. Result of keyword search

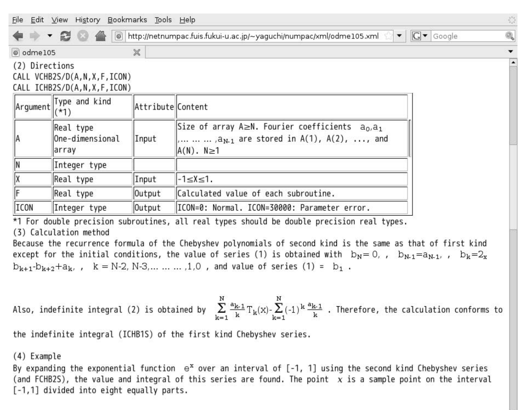

Fig. 4. Example of manual page for MathML

an user wants to use, among more than 200 manuals and a thousand source programs, is easy either by traversing the classification tree similar to the GAMS system [5], [7] or by using the keywords. Figure 2 shows the top class of NetNUMPAC and subclasses and Figure 3 shows an example of a result of the keyword search. Manual pages for MathML are also available, see Figure 4.

2) Downloading any routine supplied in NUMPAC is allowed to those who are registered in a member list of an user's group[1]. Anyone who belongs to non-profit organization is eligible for a member.
3) A template interface to the source programs gives a novice user a simple way to compute with the NUMPAC programs.
4) Running test programs illustrated in manuals on the WWW may be a convenient way to inspect how the source program corresponding to the manual works.
5) Graphical interfaces to display computed results in 2D or 3D graphics, in particular, for special functions or interpolations, are available.

In the next section the last facility mentioned above will be described in some details.

IV. Graphical Display System

This section explains a 3D graphics system for NUMPAC. Each NUMPAC routine has its own test program to illustrate the use of the routine and computed (numerical or graphical) results. To demonstrate the graphical results, NetNUMPAC provides a graphic system, that displays the computed results in 2D or 3D graphics on Web pages. To achieve this facility, Java is useful, in particular, for the dynamical and interactive display on Web pages, where client users set values of arguments of function subprograms and the ranges of coordinate axes for

[1]One could purchase NUMPAC in an entire set with Fujitsu Ltd.

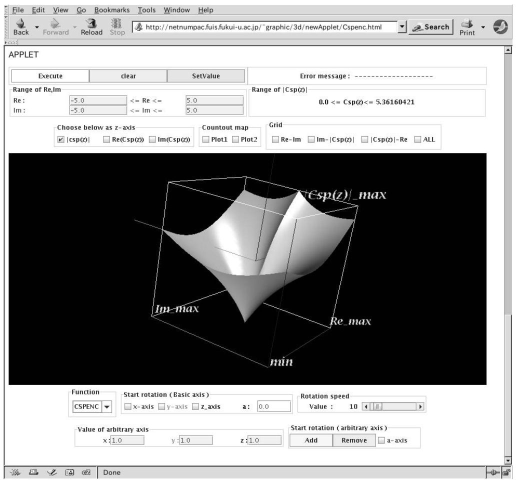

Fig. 5. 3D display of Spence function with input forms to specify the figure position

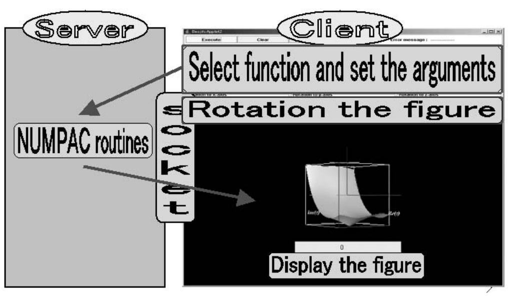

Fig. 6. Overview of 3D graphical display system on NetNUMPAC

displaying figures, see Figure 5. In this connection, the client-server system is also used to communicate between both client and server machines so that figures may be displayed on the client machine after the computations are performed on the server machine installing NUMPAC routines to prepare the data required to produce graphics. Figure 6 shows the overview of this graphical display system.

Now, twenty three special functions of NUMPAC routines, see Tab. I, are available to be displayed in 3D graphics on Web pages, where clients can choose the function name of special functions above and the way of displaying, namely the addition of the contour map, the grid mesh and/or the automatic rotation of the figure displayed. In the facility of the automatic rotation above users can choose the rotation axis arbitrarily as well as rotational speed, see Figures 7 and 8. In addition the mouse operation enables users to translate, rotate or enlarge the displayed graphics. These operations are possible by using Java3D as follows:

1. Function to specify rotational angle
   This function is achieved by using Thread class of Java3D. When users input the numerical value to the text field and start rotation, the figure rotates by a given angle and then stop.

TABLE I
AVAILABLE FUNCTIONS FOR 3D GRAPHICAL DISPLAY SYSTEM ON NETNUMPAC

function name	description
CFS2A,SFS1A	Surface fitting by splines
HERM32	Surface fitting by the piecewise Hermite interpolation formula (3-degrees)
HERM52	Surface fitting by the piecewise Hermite interpolation formula (5-degrees)
TRIPCK	Two dimensional C^k interpolation scheme for irregularly spaced data
AICGAM	Incomplete Gamma functions
BETIC	Incomplete Beta integral
CGAMMA	Gamma functions for complex arguments
DILOG	Dilogarithm
HYPGM	Hypergeometric series
CHPGM	Confluent hypergeometric series
ICEILS	Incomplete elliptic integrals of the first and second kind
JACELS	Jacobian elliptic functions
CSPENC	Spence functions
BJF	Bessel functions of the first kind of fractional order
BIF	Modified Bessel functions of the first kind of fractional order
BYF	Bessel functions of the second kind of fractional order
BKF	Modified Bessel functions of the second kind of fractional order
BESJFC	Bessel functions of fractional order with complex argument
BESIFC	Modified Bessel functions of fractional order with complex argument
BESJNC	Bessel functions of integral order with complex argument
BESINC	Modified Bessel functions of integral order with complex argument
BESYNC	Bessel functions of the second kind of integral order with complex argument
BESKNC	Modified Bessel functions of the second kind of integral order with complex argument

2. Automatic rotation around a given axis
   This function is achieved by using addChild and removeChild method. When users specify values of 3D vector for an axis around which users wish to rotate the figure, it rotates automatically around the given axis.
3. Function to operate solid figure with mouse
   This function is achieved by using MouseBehavior class. The figure rotates, zooms and moves by dragging mouse buttons on the left, the center and the right, respectively.

NetNUMPAC 3D graphical system can display more than one objects on the same screen, see Figure 9. Moreover, a system to plot images of user-defined functions is available. In this connection, a user inputs arbitrary bivariate functions including standard mathematical functions in Fortran and special functions in NUMPAC library, and can show 3D images of input functions. Figure 10 shows an example of the 3D graph of the user-defined function.

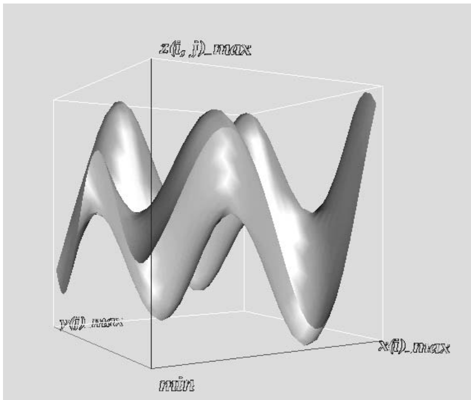

Fig. 7. 3D display of Hermite interpolation

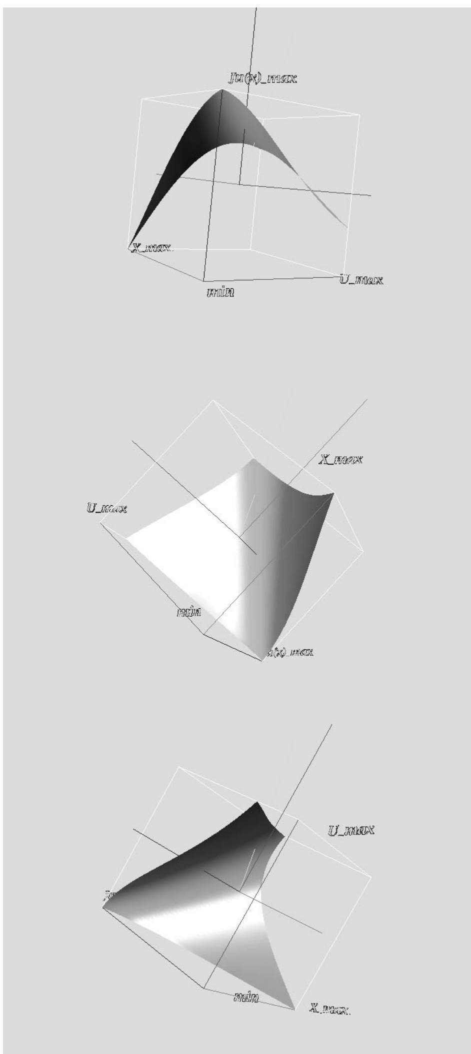

Fig. 8. Displays of automatic rotation of Bessel function with complex argument around an axis specified by the user.

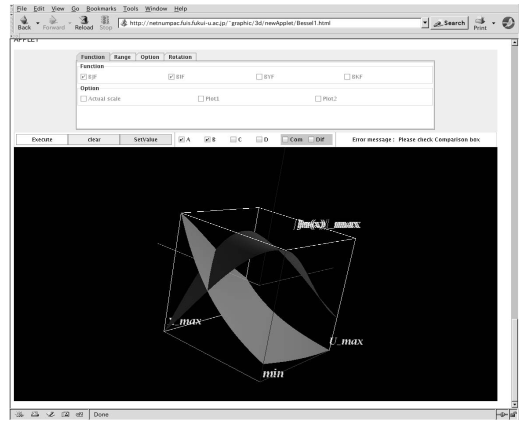

Fig. 9. Example of displaying two objects on the same screen

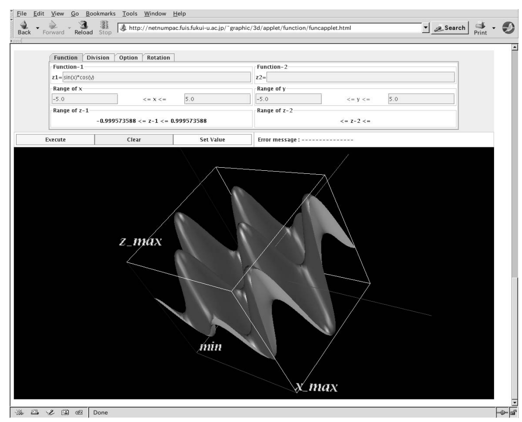

Fig. 10. Example of displaying user-defined function

V. Conclusion

NetNUMPAC is an online system on the WWW for the mathematical software package NUMPAC. This system offers considerable services both in Japanese and in English, such as retrieving manual by keyword search and classification tree, simple template for computing with NUMPAC routine, downloading source programs, and getting computed results of test programs in graphical images. Especially, the graphical system in NetNUMPAC provides three dimensional images of special functions in dynamically and interactively on Web pages by using Java. Now, twenty three special functions of NUMPAC routines are available for this system. Moreover, a user can input arbitrary bivariate functions and get 3D images of these functions by using the NetNUMPAC graphical system.

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