Web Service “Mathematical Partner” http://mathpar.com

G. Malaschonok
Tambov State University
malaschonok@gmail.com

III Международная конференция «Облачные вычисления. Образование. Исследования. Разработка»

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Introduction

– Mathpar is a web service which situated at http://mathpar.com.

– The handbook of Mathpar and many help pages of this on-line mathematical service may be found in this website.

– The Mathpar language is some *active* TeX language, which admits to do operations and to write procedures and functions in TeX.

Environment for mathematical objects

To select the environment you have to set the *algebraic structure*.

By default, a space of the three real variables is defined

$$\mathbb{R}64[x, y, z].$$

This is ring of polynomials with coefficients in the ring of real numbers.
The variables are separated
The variables are arranged in order from left to right.

User can change the environment:
For example the space

$$\mathbb{Q}[x, y, z]$$

may be suitable to solve many problems of school mathematics.

The installation command should be the follow: SPACE = Q [x, y, z];
Moving a mathematical object from the previous environment to the current environment, as a rule, should be performed explicitly, using the function

$$toNewRing()$$

In some cases, such a transformation to the current environment is automatic.

All other names which are not listed as a variables can be chosen arbitrarily by the user for any mathematical object.
For example

$$a = x + 1, \quad f = \backslash sin(x + y) - a.$$

The rule:

If the object name begins with a *capital letter* such object is an element of a *noncommutative* algebra.
If the object name begins with a *lowercase letter* such object is an element of a *commutative* algebra.

Numerical sets with standard operations

Z — the set of integers $\mathbb{Z}$,
Zp — a finite field $\mathbb{Z}/p\mathbb{Z}$ where p is a prime number,
Zp32 — a finite field $\mathbb{Z}/p\mathbb{Z}$ where p is less 2^{31},
Z64 — the ring of integer numbers z such that $-2^{63} \leqslant z < 2^{63}$,
Q — the set of rational numbers,
R — approximate real numbers with arbitrary mantissa,
R64 — standard floating-point 64-bit numbers
R128 — floating-point 64-bit numbers, equipped 64-bit for the order,
C — complexification of R,
C64 — complexification of R64,
C128 — complexification of R128,
CZ — complexification of of Z,
CZp — complexification of Zp,
CZp32 — complexification of Zp32,
CZ64 — complexification of Z64,
CQ — complexification of Q.

Examples of simple commutative polynomial rings:
SPACE = Z [x, y, z];
SPACE = R64 [u, v];
SPACE = C [x].

Several numerical sets

The ring $Z[x, y, z]Z[u, v, w]$, which has two subsets of variables, is the polynomial ring with variables u, v, w with coefficients in the polynomial ring $Z[x, y, z]$.

$$C[z]R[x,\ y]Z[n,\ m]$$

allows to have the five names of variables, which defined in the sets $\mathbb{C}$, $\mathbb{R}$ and $\mathbb{Z}$, respectively. It has the properties: If the polynomial does not contain the variables z, x, y, then it is a polynomial with coefficients in the set $\mathbb{Z}$. If the polynomial does not contain the variable z, then it is a polynomial with coefficients in the set $\mathbb{R}$.

Examples:

SPACE=Z[x, y]Z[u]; SPACE=R64[u, v]Z[a, b]; SPACE=C[x]R[y, z];

Group algebras

The definition of the group algebra has the form KG, where K is a commutative ring of scalars and G — is a group of noncommutative operators with finite number of generators. Names of these generators should begin with capital letters.

For example, the following group algebras may be defined:

$SPACE = Z[x, y]G[U, V]$; (generators U, V),

$SPACE = R64[u, v]G[A, B]$; (generators A, B),

$SPACE = C[]G[X, Y, Z, T]$; (generators X, Y, Z, T).

Each element of such algebra may be considered as a sum of terms with functional coefficients.

$R64[t, y]G[X,\ Y,\ Z]$ — is the free group algebra over a function field of two variables t, y over the field $\mathbb{R}64$ with three noncommutative generators X, Y, Z. For example,

$A = (t^2 + 1)X + \sin(t)Y + 3X^2y^3 + (t^2 + 1)XY^3X^2Y^{-2}X^2$ —is an element of such algebra.

Constants

ACCURACY — an amount of exact decimal positions in the fractional part of a real numbers of type R in the result of multiplication or division operation.
FLOATPOS —an amount of decimal positions of the real number of type R or R64, which you can see in the printed form.
ZERO_R — a machine zero for R and C numbers.
ZERO_R64 — a machine zero for R64, R128, C64 and C128 numbers.
MOD32 — the module for a finite field of the type Zp32, its value is not greater than 2^{31}.
MOD — the module for a finite field of the type Zp.
To set the machine zero $1/10^9$ (i.e. $1E-9$), you can use the commands $ZERO\_R = 9$ or $ZERO\_R64 = 9$.

Example.

```
SPACE=Zp32[x, y];
MOD32=7;
f=37x+42y+55;
g=2*f;
\print(f , g );
```

The results:

f = 2x-1;

g = 4x+5.

Idempotent algebra and tropical mathematics

User can uses the idempotent algebras. In this case the signs of "addition"and "multiplication"for the infix operations can be used for operations in tropical algebra: min, max, addition, multiplication.
Each numerical sets $\mathbb{R}$, $\mathbb{R}64$, $\mathbb{Z}$ has two additional elements ∞ and $-\infty$, and they have different elements, which is play the role of zero and unit. We denote these sets $\hat{\mathbb{R}}$, $\hat{\mathbb{R}}64$, $\hat{\mathbb{Z}}$, correspondingly. The name of tropical algebra is obtained from three words: (1) a numerical set, (2) an operation, which corresponding to the sign *plus* and (3) an operation, which corresponding to the sign *times*.
The algebras *R64MaxPlus*, *R64MinPlus*, *R64MaxMin*, *R64MinMax*, *R64MaxMult*, *R64MinMult* are defined for the numerical set $\hat{\mathbb{R}}64$.
RMaxPlus, RMinPlus, RMaxMin, R64MinMax, RMaxMult, RMinMult are defined for the numerical set $\hat{\mathbb{R}}$.
ZMaxPlus, ZMinPlus, ZMaxMin, ZMinMax, ZMaxMult, ZMinMult are defined for the numerical set $\hat{\mathbb{Z}}$.

For example, for the algebra *ZMaxPlus* you can do the following operations.

Example.

SPACE=ZMaxPlus[x, y];
a=2; b=9+x; c=a+b; d=a*b+y;
\print(c, d);
The results: $c = x + 9$; $d = y + 2 * x + 11$.

For each algebra we defined elements $\mathbf{0}$ and $\mathbf{1}$, $-\infty$ and ∞.
For each element a we defined the operation of closure: $a^{\times}$, i.e. the amount of $1 + a + a^2 + a^3 + \ldots$. For the classical algebras this operation is equivalent to $(1 - a)^{-1}$, for $|a| < 1$.

The calculations on a supercomputer

In order to solve computational problems that require large computation time or large amounts of memory, the system has special functions that provide the user with resources of supercomputer. These functions allow you to perform calculations not on a single processor and on a dedicated set of cores supercomputer. The number of kernels ordered by the user. You have the following functions (*parfunctions*) that apply to supercomputer:

1) *gbasisPar* — computation of Grobner basis;
2) *adjointPar* — computation of the adjoint matrix;
3) *adjointDetPar* — computation of the adjoint matrix and determinant of the matrix;
4) *echelonFormPar* — computation of the matrix echelon form;
5) *inversePar* — computation of the inverse matrix;
6) *detPar* — computation of the determinant of the matrix;
7) *kernelPar* — computation of the kernel of a linear operator;
8) *charPolPar* — computation of the characteristic polynomial;
9) *multiplyPar* — calculation of the matrix product;
10) *multiplyPar* — computation of the product of polynomials.

Before applying any of these functions, the user must specify the parameters that define the parallel environment:
TOTALPROCNUMBER — total number of processors (cores), which provides for the computations,
NODEPROCNUMBER — number of cores on a single node,
CLUSTERTIME — maximum time (in minutes) execution of the program, after which the program is forced to end.
To set the number of cores on a single node the user must know what a cluster is used and how many cores it is available on the node. By default, the *TOTALPROCNUMBER* and *NODEPROCNUMBER* installed so that all the cores were used per node, and $CLUSTERTIME = 1$.
The user can change the number of cores in a single node. This is an important feature, since the memory on a single node is used by all cores in this node. Consequently, the user can regulate the size of RAM that is available to one core.
Only users of the cluster of Tambov State University can perform parallel computing for today.

РЕЗЮМЕ

Целью проекта Mathpar является создание общедоступного математического веб-сервиса «Математический Партнер», который предназначен для решения стандартных математических задач. Реализация проекта может привести к качественно новому функционированию математического знания в обществе.

(1) В образовании.

Используя активную среду веб-сервиса, можно будет осваивать математику и все естественные дисциплины со значительно большей эффективностью, чем традиционным путем. Освобождение от рутинных выкладок позволит сосредоточиться на принципиальных вопросах естественных дисциплин. Станет эффективнее процесс отражения знаний учеником и процесс контроля его знаний учителем. Сократится разрыв в образовательном уровне в разных учебных заведениях и в разных странах.

(2) В научном образовании и культуре.

Повысится общий культурный уровень общества в результате существенно возросшего уровня математического образования, простоте и эффективности его применения с использованием веб-сервиса. Углубление математического знания приведет к ускорению развития всех естественных наук. Особенно сильно изменения затронут научное образование.

(3) В развитии естественных наук и технологий.

Отдельной частью проекта является инструментарий решения масштабных математических задач на суперкомпьютере. Наличие такого мощного общедоступного математического инструмента скажется на темпах научно-технического развития общества.

(4) В информационных технологиях.

Веб-сервис может функционировать как RESTful Web Services. При этом любое клиентское приложение сможет сформулировать задание и обратиться к веб-сервису. Результат выполнения задания, полученный от веб-сервиса, может быть сразу использован этим приложением для решения конкретной прикладной задачи.

Работа поддержана РФФИ (гр. 12-07-00755).

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- G. I.Malaschonok, Computer mathematics for computational network Tambov University Reports. Series: Natural and Technical Sciences. **15** Issue. 1. (2010), 322–327.
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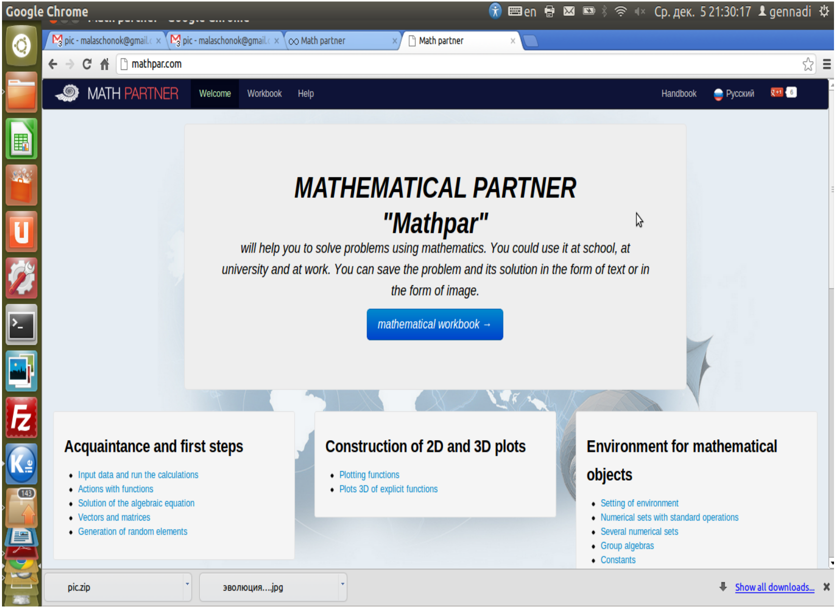
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Plots 3D of explicit functions
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Setting of environment
Numerical sets with standard operations
Several numerical sets
Group algebras
Constants
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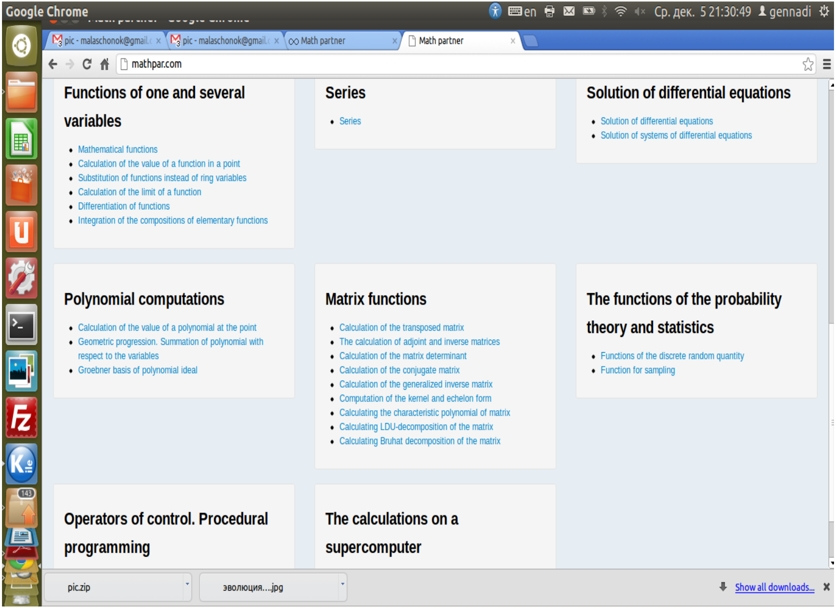
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Differentiation of functions
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Series
Series
Solution of differential equations
Solution of differential equations
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The calculation of adjoint and inverse matrices
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5.5 Differentiation of functions

To differentiate a function $f(x, y, z)$ with lowest variable x, you have to execute one of commands D(f), D(f,x) or D(f,x{ \widehat{ } 1)}. To fine the second deriv variable y, you have to execute the command D(f,y{ \widehat{ } 2)}. And so on.

To find a mixed first-order derivative of the function f there is a command D(f, [x, y]), to find the derivative of higher order to use the command D(f,[x { \widehat{ { }\widehat{ } n])}, where k, m, n indicate the order of the derivative.

```
SPACE = Z[x, y];
f = \sin(x^2 + \tg(y^3 + x));
h = \D(f, y);
\print(h);
```

```
SPACE = Z[x, y];
f = \sin(x^2 + \tg(y^3 + x));
h = \D(f);
\print(h);
```

```
SPACE = Z[x, y, z];
f = x^8y^4z^9;
g = \D(f, [x^2, y^2, z^2]);
\print(g);
```

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variable y, you have to execute the command D(f,y{ \widehat{ } 2)}. And so on.

To find a mixed first-order derivative of the function f there is a command D(f, [x, y]), to find the derivative of higher order to use the command D(f,[x { \widehat{ { }\widehat{ } n])}, where k, m, n indicate the order of the derivative.

$$SPACE = Z[x,y];$$
$$f = \mathbf{sin}(x^2 + \mathbf{tg}(y^3 + x));$$
$$h = D_y(f);$$
$$\mathbf{print}(h);$$
$$out:$$
$$h = 3y^2 \cdot \mathbf{cos}(x^2 + \mathbf{tg}(y^3 + x))/(\mathbf{cos}(y^3 + x))^2;$$

$$SPACE = Z[x,y];$$
$$f = \mathbf{sin}(x^2 + \mathbf{tg}(y^3 + x));$$
$$h = D_x(f);$$
$$\mathbf{print}(h);$$
$$out:$$
$$h = (2x \cdot \mathbf{cos}(x^2 + \mathbf{tg}(y^3 + x)) \cdot (\mathbf{cos}(y^3 + x))^2 + \mathbf{cos}(x^2 + \mathbf{tg}(y^3 + x)))/(\mathbf{cos}(y^3 + x))^2;$$

$$SPACE = Z[x,y,z];$$
$$f = x^8 y^4 z^9;$$
$$g = D_{[x^2 y^2 z^2]}(f);$$
$$\mathbf{print}(g);$$
$$out:$$
$$g = 48384 z^7 y^2 x^6;$$

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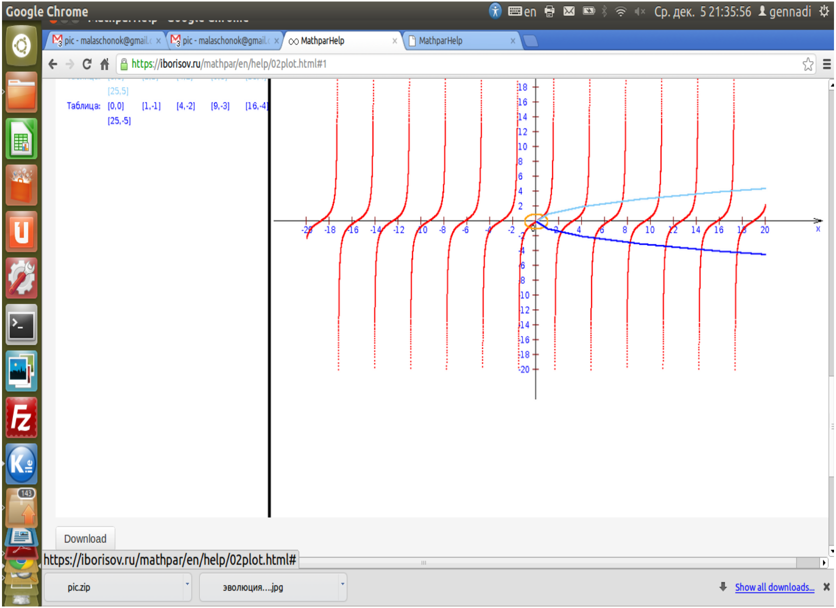
```
    ],
    [-10, 10, -10, 10]);
```

Construction of various plots of functions in one coordinate system

To construct the plots of functions defined in different ways, you must first build a plot of each function and then execute the command showPlots([f_1, f_2, ..., f_n]).

You can specify the signature of the axes of the graph and its caption. It's enough to run showPlots([f1, f2, f3, f4], ['x', 'y', 'title']), instead of specifying 'x' — signature on the axis OX, instead of 'y' — signature on the axis OY, instead of the 'title' \, — the header graphic. Default is ['x' , 'y' , ' '].

```
f1 = \plot(\tg(x), [-20, 20, -20, 20]);
f2=\tablePlot(
    [
      [0, 1, 4, 9, 16, 25],
      [0, 1, 2, 3, 4, 5]
    ],
    [-10, 10, -10, 10]);
f3 = \paramPlot([\sin(x), \cos(x)], [-10, 10]);
f4 = \tablePlot(
    [
      [0, 1, 4, 9, 16, 25],
      [0, -1, -2, -3, -4, -5]
    ],
    [-10, 10, -10, 10]);
\showPlots([f1, f2, f3, f4],
    ['x', 'y', 'The functions f1,  f2,  f3,  f4,  f5']);
```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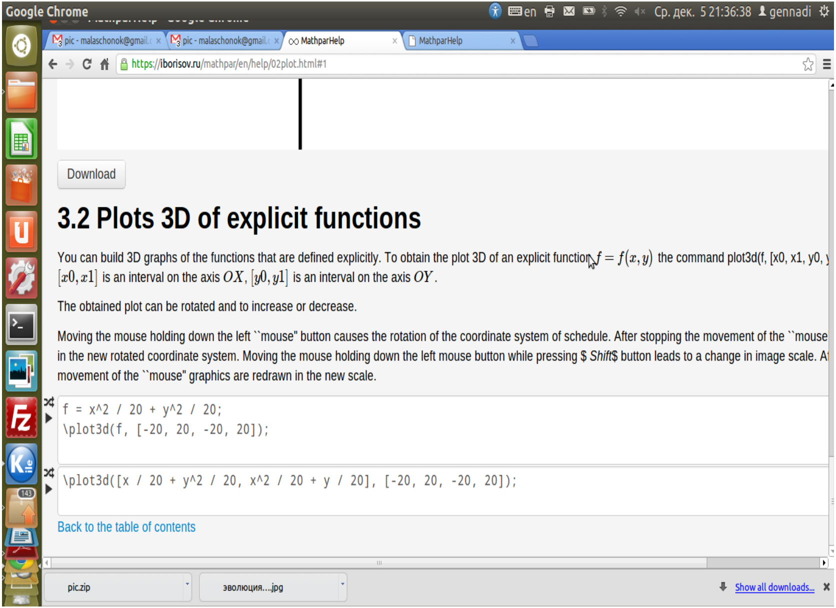
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3.2 Plots 3D of explicit functions
You can build 3D graphs of the functions that are defined explicitly. To obtain the plot 3D of an explicit function f = f(x,y) the command plot3d(f, [x0, x1, y0,
[x0, x1] is an interval on the axis OX, [y0, y1] is an interval on the axis OY.
The obtained plot can be rotated and to increase or decrease.
Moving the mouse holding down the left ``mouse" button causes the rotation of the coordinate system of schedule. After stopping the movement of the ``mouse
in the new rotated coordinate system. Moving the mouse holding down the left mouse button while pressing $ Shift$ button leads to a change in image scale. A
movement of the ``mouse" graphics are redrawn in the new scale.
f = x^2 / 20 + y^2 / 20;
\plot3d(f, [-20, 20, -20, 20]);
\plot3d([x / 20 + y^2 / 20, x^2 / 20 + y / 20], [-20, 20, -20, 20]);
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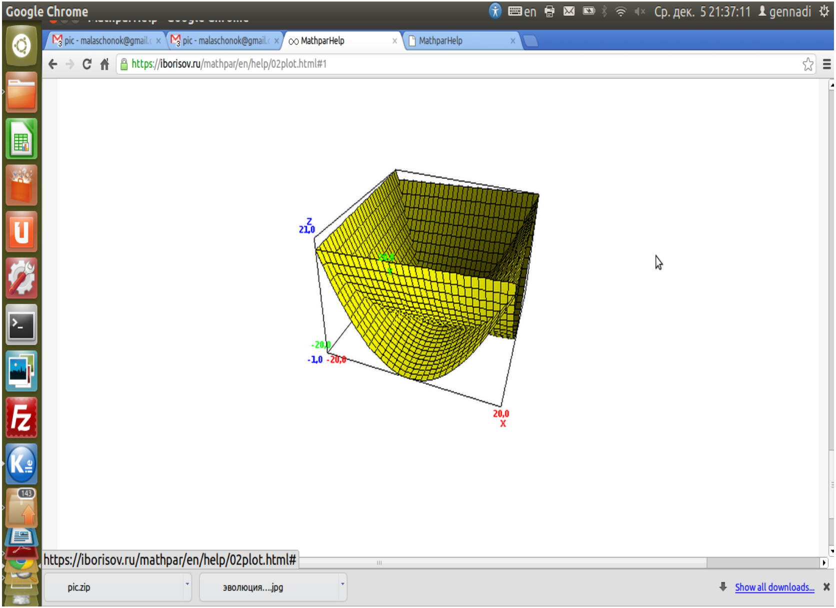
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7.2 Solution of systems of differential equations

Procedure of solving a system of differential equations (SDE) consists of four parts.

1. To set the ring ($SPACE$).
2. To set a system of equations (systLDE).
3. To set initial conditions (initCond).
4. To get solution of SDE (solveLDE).

```
SPACE=R64[t];
g=\systLDE(\d(x, t)-y+z=0, -x-y+\d(y, t)=0, -x-z+\d(z, t)=0);
f= \initCond(\d(x, t, 0, 0)=1, \d(y, t, 0, 0)=2,
             \d(z, t, 0, 0)=3);
h= \solveLDE(g, f);
\print(h);
```

```
SPACE=R64[t];
g=\systLDE(\d(x, t, 2)+\d(x, t)-\d(y, t)=1,
           \d(x, t)+x-\d(y, t, 2)=1+4\exp(t));
f=\initCond(\d(x, t, 0, 0)=1, \d(x, t, 0, 1)=2,
            \d(y, t, 0, 0)=0, \d(y, t, 0, 1)=1);
h= \solveLDE(g, f);
\print(h);
```

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7.2 Solution of systems of differential equations

Procedure of solving a system of differential equations (SDE) consists of four parts.

1. To set the ring ($SPACE$).
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4. To get solution of SDE (solveLDE).

$SPACE = R64[t];$

$$g = \begin{cases} x'_t - y + z &= 0 \\ -x - y + y'_t &= 0; \\ -x - z + z'_t &= 0 \end{cases}$$

$$f = \begin{cases} x^{(0)}_{t=0} &= 1 \\ y^{(0)}_{t=0} &= 2; \\ z^{(0)}_{t=0} &= 3 \end{cases}$$

$h = \mathbf{solveLDE}(g, f);$

$\mathbf{print}(h);$

out :

$h = [((-2) + 5.00 \cdot e^t + (-1.00 \cdot e^t) \cdot t), (2 + (-1.00 \cdot e^t)), ((-2) + 4.00 \cdot e^t + (-1.00 \cdot e^t) \cdot t)];$

```
SPACE=R64[t];
g=\systLDE(\d(x, t)-8y+x=0, \d(y, t)-x-y=0);
f= \initCond(\d(x, t, 0, 0)=a, \d(y, t, 0, 0)=b);
h= \solveLDE(g, f);
\print(h);
```

```
SPACE=R64[t];
g=\systLDE(\d(x, t)+3x-4y=9(\exp(t))^2, \d(y, t)+2x-3y=3(\exp(t))^2);
f= \initCond(\d(x, t, 0, 0)=2, \d(y, t, 0, 0)=0);
h= \solveLDE(g, f);
\print(h);
```

```
SPACE=R64[t];
g=\systLDE(\d(x, t, 2)+\d(y, t)=\sh(t)-\sin(t)-t, \d(y, t, 2)-\d(x, t)=\ch(t)-\cos(t));
f=\initCond(\d(x, t, 0, 0)=2, \d(x, t, 0, 1)=0,
            \d(y, t, 0, 0)=0, \d(y, t, 0, 1)=1);
h=\solveLDE(g, f);
\print(h);
```

```
SPACE=R64[t];
g=\systLDE(\d(x, t)+5y-4x=0, \d(y, t)-x=0);
f= \initCond(\d(x, t, 0, 0)=0, \d(y, t, 0, 0)=1);
```

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$SPACE = R64[t];$

$$g = \begin{cases} x'_t - 8y + x & = & 0 \\ y'_t - x - y & = & 0 \end{cases};$$

$$f = \begin{cases} x^{(0)}_{t=0} & = & a \\ y^{(0)}_{t=0} & = & b \end{cases};$$

$h = \mathbf{solveLDE}(g, f);$

$\mathbf{print}(h);$

out :

$h = [(((-48.00 \cdot b) + 24.00 \cdot a)/36.00 \cdot e^{-3.00t} + (48.00 \cdot b + 12.00 \cdot a)/36.00 \cdot e^{3.00t}), (((-6.00 \cdot a) + 12.00 \cdot b)/36.00 \cdot e^{-3.00t} + (6.00 \cdot a + 24.0$

$SPACE = R64[t];$

$$g = \begin{cases} x'_t + 3x - 4y & = & 9(e^t)^2 \\ y'_t + 2x - 3y & = & 3(e^t)^2 \end{cases};$$

$$f = \begin{cases} x^{(0)}_{t=0} & = & 2 \\ y^{(0)}_{t=0} & = & 0 \end{cases};$$

$h = \mathbf{solveLDE}(g, f);$

$\mathbf{print}(h);$

out :

$h = [(e^t + e^{2.00t}), (e^t + (-1.00 \cdot e^{2.00t}))];$

```
SPACE=R64[t];
```

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9.8 Calculating LDU-decomposition of the matrix

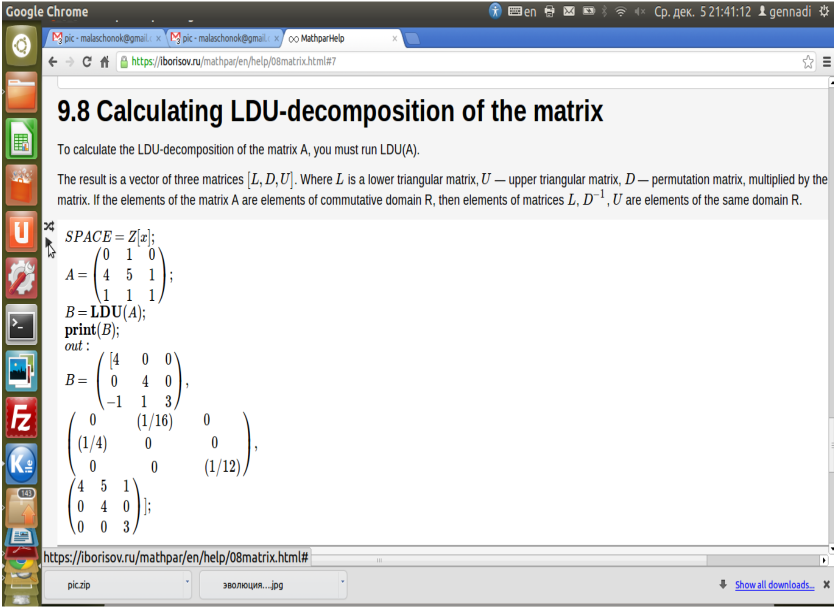
To calculate the LDU-decomposition of the matrix A, you must run LDU(A).

The result is a vector of three matrices $[L, D, U]$. Where L is a lower triangular matrix, U — upper triangular matrix, D — permutation matrix, multiplied by the matrix. If the elements of the matrix A are elements of commutative domain R, then elements of matrices L, D^{-1}, U are elements of the same domain R.

```
SPACE=Z[x];
A=[[0, 1, 0], [4, 5, 1],[1, 1, 1]];
B=\LDU(A);
\print(B);
```

```
SPACE=Z[x];
A=[[1, 4,0,1], [4, 5,5,3],[1,2,2,2],[3,0,0,1]];
B=\LDU(A);
\print(B);
```

```
SPACE=Z[x,y];
A=[[\cos(y),\sin(x)],[\sin(y),\cos(x)]];
B=\LDU(A);
\print(B);
```



9.8 Calculating LDU-decomposition of the matrix

To calculate the LDU-decomposition of the matrix A, you must run LDU(A).

The result is a vector of three matrices $[L, D, U]$. Where L is a lower triangular matrix, U — upper triangular matrix, D — permutation matrix, multiplied by the matrix. If the elements of the matrix A are elements of commutative domain R, then elements of matrices L, D^{-1}, U are elements of the same domain R.

$$SPACE = Z[x];$$

$$A = \begin{pmatrix} 0 & 1 & 0 \\ 4 & 5 & 1 \\ 1 & 1 & 1 \end{pmatrix};$$

$$B = \mathbf{LDU}(A);$$

$$\mathbf{print}(B);$$

out :

$$B = \left[\begin{pmatrix} 4 & 0 & 0 \\ 0 & 4 & 0 \\ -1 & 1 & 3 \end{pmatrix}, \begin{pmatrix} 0 & (1/16) & 0 \\ (1/4) & 0 & 0 \\ 0 & 0 & (1/12) \end{pmatrix}, \begin{pmatrix} 4 & 5 & 1 \\ 0 & 4 & 0 \\ 0 & 0 & 3 \end{pmatrix} \right];$$

```
A=[[\cos(y),\sin(x)],[\sin(y),\cos(x)]];
B=\LDU(A);
\print(B);
```

9.9 Calculating Bruhat decomposition of the matrix

To calculate the Bruhat decomposition of the matrix A, you must run BruhatDecomposition(A).

The result is a vector of three matrices $[V, D, U]$. Where V and U — upper triangular matrices, D — permutation matrix, multiplied by the inverse of the diago elements of the matrix A are elements of commutative domain R, then elements of matrices V, D^{-1}, U are elements of the same domain R.

```
SPACE=Z[x];
A=[[1, 4,0,1], [4, 5,5,3],[1,2,2,2],[3,0,0,1]];
B=\BruhatDecomposition(A);
\print(B);
```

```
SPACE=Z[x,y];
A=[[\cos(y),\sin(x)],[\sin(y),\cos(x)]];
B=\BruhatDecomposition(A);
\print(B);
```

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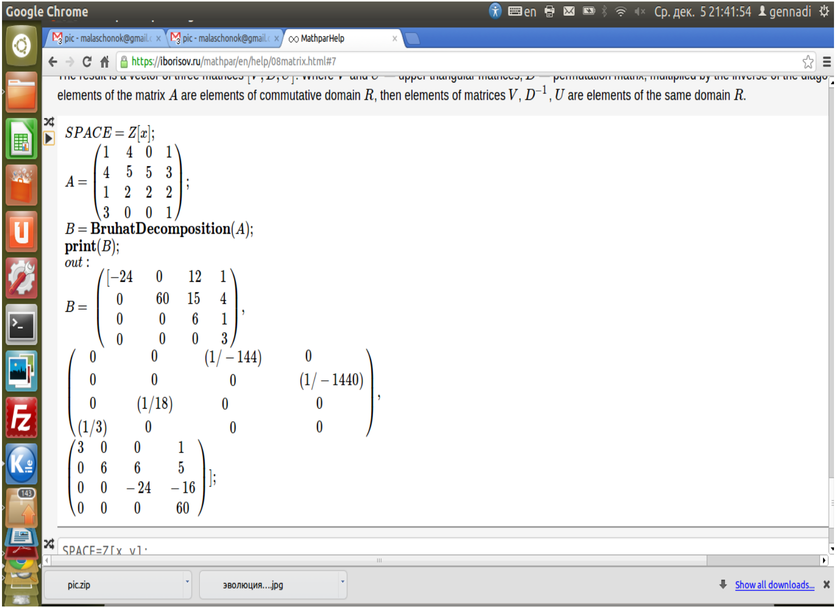
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gennadi
pic - malaschonok@gmail.c
pic - malaschonok@gmail.c
MathparHelp
https://iborisov.ru/mathpar/en/help/08matrix.html#7
elements of the matrix A are elements of commutative domain R, then elements of matrices V, D^{-1}, U are elements of the same domain R.
$SPACE = Z[x];$
$A = \begin{pmatrix} 1 & 4 & 0 & 1 \\ 4 & 5 & 5 & 3 \\ 1 & 2 & 2 & 2 \\ 3 & 0 & 0 & 1 \end{pmatrix};$
$B = \mathbf{BruhatDecomposition}(A);$
$\mathbf{print}(B);$
out :
$B = \begin{pmatrix} -24 & 0 & 12 & 1 \\ 0 & 60 & 15 & 4 \\ 0 & 0 & 6 & 1 \\ 0 & 0 & 0 & 3 \end{pmatrix},$
$\begin{pmatrix} 0 & 0 & (1/-144) & 0 \\ 0 & 0 & 0 & (1/-1440) \\ 0 & (1/18) & 0 & 0 \\ (1/3) & 0 & 0 & 0 \end{pmatrix},$
$\begin{pmatrix} 3 & 0 & 0 & 1 \\ 0 & 6 & 6 & 5 \\ 0 & 0 & -24 & -16 \\ 0 & 0 & 0 & 60 \end{pmatrix}];$
SPACE=Z[x,y];
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