

# Ryacas – an R interface to the `yacas` computer algebra system – Sym version

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## 1 Introduction

`Ryacas` makes the `yacas` computer algebra system available from within R. (`yacas` is short for “Yet Another Computer Algebra System”).

This document is based on the `yacas` Sym interface and is similar to another document based on the interface provided by R `yacas` function.

**yacas** is developed by Ayal Pinkhuis (who is also the maintainer) and others, and is available at [yacas.sourceforge.org](http://yacas.sourceforge.org) for various platforms. There is a comprehensive documentation (300+ pages) of **yacas** (also available at [yacas.sourceforge.org](http://yacas.sourceforge.org)) and the documentation contains many examples. The examples given here are largely taken from the **yacas** documentation (especially from the introductory chapter) but are organised differently.

A **Sym** object is a **yacas** character string that has the "Sym" class. Using +, - and other similar R operators. One can combine **Sym** objects with other **Sym** objects as well as to other R objects. **Sym(x)** coerces object **x** to a **Sym** object by first coercing it to character and then changing its class to "Sym". One can also apply **sin**, **cos**, **tan**, **deriv**, **Integrate** and other provided functions to **Sym** objects as shown in the examples below.

## 2 A sample session

Algebraic calculations:

```
> (Sym(10) + Sym(2)) * Sym(5) + Sym(7)^Sym(7)
823603;
> Sym("10 * 2") * 5 + Sym(7)^7
823643;
> (Sym(10) + 2) * 5 + Sym(7)^7
823603;
> Sym("(10+2)*5 + 7^7")
823603;
> Sym("1/14 + 5/21 * (30 - 1+1/2)")
149/21;
```

Numerical evaluations:

```
> Sym("-12/2")
-6;
> Eval(Sym("-12/2"))
NULL
```

Working with symbolic expressions:

```
> x <- Sym("x")
> Factor(x^2 - 1)
(x+1)*(x-1);
> exp1 <- x^2 + 2 * x^2
> exp0 <- Sym("exp0")
> exp2 <- 2 * Sym(exp0)
> exp3 <- 6 * Pi * x
> exp4 <- exp1 * (1 - sin(exp3))/exp2
> exp4
(3*x^2*(1-Sin(6*x*Pi)))/(2*exp0);
```

Working with numerical expressions: ....

Combining symbolic and numerical expressions:

```
> N(sin(1)^2 + cos(x)^2)
Cos(x)^2+0.708073418273571;
```

Differentiation:

```
> deriv(sin(x), x)
Cos(x);
```

Integration: [!!! This is odd: I thought yacas was case sensitive...]]

```
> Set(A, "ssss")
ssss;
> A <- Sym("A")
> a <- Sym("a")
> b <- Sym("b")
> Integrate(sin(x), x, a, b)
In function "Check" : CommandLine(1) : "Found bound variable A which should have been unbound, in MatchLin
> Clear("A")
True;
> Integrate(sin(x), x, a, b)
In function "Check" : CommandLine(1) : "Found bound variable B which should have been unbound, in MatchLin
```

Expanding polynomials:

```
> Expand((1 + x)^3)
x^3+3*x^2+3*x+1;
```

Taylor expansion:

```
> texp <- Taylor(exp(x), x, 0, 3)
```

Printing the result in nice forms:

```
> PrettyForm(texp)
      2      3
      x      x
x + -- + -- + 1
      2      6
> TeXForm(texp)
"$x + \frac{x ^{2}}{2}  + \frac{x ^{3}}{6}  + 1$";
```

## 3 Simple Yacas calculations

### 3.1 Setting and clearing a variable

The function Set() command can both be used to assign values to global variables.

```

> Set(n, "(10 + 2) * 5")
60;
> n <- Sym("n")
> Set(n, n + n)
120;
> a <- Sym("a")
> Set(z, cos(a))
Cos(a);
> z <- Sym("z")
> z + z
2*Cos(a);

```

To clear a variable binding execute `Clear()`:

```

> Set(n, 1)
1;
> n <- Sym("n")
> n
1;
> Clear(n)
True;
> n
n;

```

### 3.2 Symbolic and numerical evaluations, precision

Evaluations are generally exact:

```

> exp(0)
[1] 1
> exp(1)
[1] 2.718282
> sin(Pi/4)
Sqrt(1/2);
> Sym("355/113")
355/113;

```

To obtain a numerical evaluation (approximation), the `N()` function can be used:

```

> N(exp(1))
2.71828182845905;
> N(sin(Pi/4))
0.707134;
> N(355/113)
3.14159292035398;

```

The `N()` function has an optional second argument, the required precision:

```
> N("355/133", 20)
2.66917293233082706767;
```

The command `Precision(n)` can be used to specify that all floating point numbers should have a fixed precision of `n` digits:

```
> Precision(5)
True;
> N("355/113")
3.14159;
```

### 3.3 Rational numbers

Rational numbers will stay rational as long as the numerator and denominator are integers:

```
> Sym("55 / 10")
11/2;
```

### 3.4 Symbolic calculation

Some exact manipulations :

```
> Sym("1/14+5/21*(1*30-(1+1/2)*5^2)")
(-12)/7;
> x <- Sym("x")
> 0 + x
x;
> y <- Sym("y")
> x + y
x+y;
> sin(asin(x)) + tan(atan(y))
x+y;
```

### 3.5 Complex numbers and the imaginary unit

The imaginary unit  $i$  is denoted `I` and complex numbers can be entered as either expressions involving `I` or explicitly `Complex(a,b)` for  $a+ib$ .

```
> I^2
-1;
> 7 + 3 * I
Complex(7,3);
> Conjugate("%")
Complex(7,-3);
> exp(3 * I)
Complex(Cos(3),Sin(3));
```

### 3.6 Recall the most recent line – the % operator

The operator % automatically recalls the result from the previous line.

```
> (1 + x)^3
(x+1)^3;
> z <- Sym("%")
> z
(x+1)^3;
```

### 3.7 Printing with PrettyForm, PrettyPrint, TexForm and TeX-Form

There are different ways of displaying the output. The (standard) yacas form is:

```
> a <- Sym("a")
> b <- Sym("b")
> c <- Sym("c")
> d <- Sym("d")
> A <- List(List(a, b), List(c, d))
> k <- Sym("k")
> B <- (1 + x)^2 + k^3
> A
{{a,b},{c,d}};
> B
(x+1)^2+k^3;
```

The Pretty form is:

```
> PrettyForm(A)
/
| ( a ) ( b ) |
|
| ( c ) ( d ) |
\
/

> PrettyForm(B)
      2      3
( x + 1 )  + k
```

An alternative is the PrettyPrinter [!!! Why does this give the same result as before??? Earlier I got XML output as well... Is something not reset???

```

> PrettyPrinter("PrettyForm")
True
> A
/          \
| ( a ) ( b ) |
|          |
| ( c ) ( d ) |
\          /
> PrettyPrinter()
True;
> A
{{a,b},{c,d}};
> PrettyPrinter("OMForm")
expression(TRUE)
> A
expression(list(list(a, b), list(c, d)))

```

The output can be displayed in TeX form as well:

```

> TeXForm(B)
expression("$\left( x + 1\right) ^{2} + k ^{3}$")

```

## 4 Commands

### 4.1 Factorial

```

> Factorial(40)
expression(Factorial(40))

```

### 4.2 Taylor expansions

Expand  $\exp(x)$  in three terms around 0 and a:

```

> Taylor(exp(x), x, 0, 3)
expression(x + x^2/2 + x^3/6 + 1)
> a <- Sym("a")
> Taylor(exp(x), x, a, 3)
expression(exp(a) + exp(a) * (x - a) + (x - a)^2 * exp(a)/2 +
(x - a)^3 * exp(a)/6)

```

The `InverseTaylor()` function builds the Taylor series expansion of the inverse of an expression. For example, the Taylor expansion in two terms of the inverse of  $\exp(x)$  around  $x=0$  (which is the Taylor expansion of  $\log(y)$  around  $y=1$ ):

```

> InverseTaylor(exp(x), x, 0, 2)
expression(x - 1 - (x - 1)^2/2)
> Taylor(log(y), y, 1, 2)
expression(y - 1 - (y - 1)^2/2)

```

## 4.3 Solving equations

### 4.3.1 Solving equations symbolically

Solve equations symbolically with:

```
> Solve(x/(1 + x) == a, x)
expression(list(x == a/(1 - a)))
> Solve(x^2 + x == 0, x)
expression(list(x == 0, x == -1))
```

(Note the use of the == operator, which does not evaluate to anything, to denote an "equation" object.) Solve() is rather limited.

### 4.3.2 Solving equations numerically

To solve an equation (in one variable) like  $\sin(x) - \exp(x) = 0$  numerically taking 0.5 as initial guess and an accuracy of 0.0001 do:

```
> Newton(sin(x) - exp(x), x, 0.5, 1e-04)
expression(-3.18306)
```

## 4.4 expanding polynomials

```
> Expand((x + 1)^3)
expression(x^3 + 3 * x^2 + 3 * x + 1)
```

## 4.5 Simplifying an expression

The function Simplify() attempts to reduce an expression to a simpler form.

```
> (x + y)^3 - (x - y)^3
expression((x + y)^3 - (x - y)^3)
> Simplify("%")
expression(6 * (x^2 * y) + 2 * y^3)
```

## 4.6 Analytical derivatives

Analytical derivatives of functions can be evaluated:

```
> deriv(sin(x), x)
expression(cos(x))
> deriv(deriv(sin(x)))
expression(-sin(x))
```

The deriv function also accepts an argument specifying how often the derivative has to be taken, e.g:

```
> deriv(sin(x), x, 2)
expression(-sin(x))
```



## 4.7 Integration

!!! Problem arises because A was defined above (a is not defined, though) (Seems ok in Sym version.)

```
> Integrate(sin(x), x, a, b)
In function "Check" : CommandLine(1) : "Found bound variable B which should have been unbound, in MatchLin
> Integrate(log(x), x, a, b)
In function "Check" : CommandLine(1) : "Found bound variable B which should have been unbound, in MatchLin
> Integrate(1/(x^2 - 1), x)
In function "Check" : CommandLine(1) : "Found bound variable B which should have been unbound, in MatchLin
> Integrate(sin(a * x)^2 * cos(b * x), x)
In function "Check" : CommandLine(1) : "Found bound variable B which should have been unbound, in MatchLin
```

## 4.8 Limits

```
> Limit(sin(x)/x, x, 0)
expression(1)
> n <- Sym("n")
> Limit((1 + (1/n))^n, n, Infinity)
expression(exp(1))
> h <- Sym("h")
> Limit((sin(x + h) - sin(x))/h, h, 0)
expression(cos(x))
```

## 4.9 Variable substitution

```
> Subst(x + x, x, cos(a))
expression(2 * cos(a))
```

## 4.10 Solving ordinary differential equations

OdeSolve notation not supported by Sym currently.

```
> yacas("OdeSolve(y' ==4*y)")
expression(C800 * exp(2 * x) + C804 * exp(-2 * x))
> yacas("OdeSolve(y' ==8*y)")
expression(C834 * exp(8 * x))
```

## 5 Matrices

```
> u1 <- Sym("u1")
> u2 <- Sym("u2")
> E4 <- List(List(u1, u1, 0), List(u1, 0, u2), List(0,
+      u2, 0))
> PrettyForm(E4)
```

$$\begin{array}{c} / \\ | \text{ ( u1 ) ( u1 ) ( 0 ) } | \\ | \text{ ( u1 ) ( 0 ) ( u2 ) } | \\ | \text{ ( 0 ) ( u2 ) ( 0 ) } | \\ \backslash \end{array}$$

### 5.1 Inverse

```
> E4i <- Inverse(E4)
> Simplify(E4i)
expression(list(list(1/u1, 0, -1/u2), list(0, 0, 1/u2), list(-1/u2,
1/u2, u1/u2^2)))
> PrettyForm(Simplify(E4i))
```

$$\begin{array}{c} / \\ | \text{ / 1 \ ( 0 ) / -1 \ } | \\ | \text{ | -- | \ -- | } | \\ | \text{ \ u1 / \ u2 / } | \\ | \text{ ( 0 ) ( 0 ) / 1 \ } | \\ | \text{ | \ -- | } | \\ | \text{ \ u2 / } | \\ | \text{ / -1 \ / 1 \ / u1 \ } | \\ | \text{ | -- | | -- | | --- | } | \\ | \text{ \ u2 / \ u2 / | \ 2 | } | \\ | \text{ \ u2 / } | \\ \backslash \end{array}$$

### 5.2 Determinant

```
> determinant(E4)
expression(-(u1 * u2^2))
> determinant(E4i)
expression(-(u1 * u2 * (u1 * u2^3))/(u1 * u2^2)^3)
> Simplify(E4i)
expression(list(list(1/u1, 0, -1/u2), list(0, 0, 1/u2), list(-1/u2,
1/u2, u1/u2^2)))
> Simplify(determinant(E4i))
expression(-1/(u1 * u2^2))
```