Chapter 1

About this tutorial

TIDES (Taylor series Integrator for Differential EquationS) is a software to integrate, by using the Taylor Series method, systems of first order differential equations (ODEs) of the form

$$\dot{\boldsymbol{y}} = \boldsymbol{f}(t, \boldsymbol{y}(t); \boldsymbol{p}), \quad \boldsymbol{y}(t_0) = \boldsymbol{y}_0, \quad \boldsymbol{y}\,(\text{variables}) \in \mathbb{R}^n, \quad \boldsymbol{p}\,(\text{parameters}) \in \mathbb{R}^m\,. \qquad (1.1)$$

To obtain TIDES follow the instructions of: `http://gme.unizar.es/software/tides` . In the same web page you will see references of papers related with TIDES.

This tutorial describes the use of TIDES. It is divided in three parts.

1. The first part contains three chapters that explain the Taylor series method, the characteristics of TIDES and how to install the software.

2. The second part describes the use of TIDES by means of examples. All the possibilities of TIDES are introduced progressively. Read this part before the first time you use TIDES.

3. The third part is a reference guide of TIDES. This part contains the full description of all the expressions and options of MathTIDES and the description of the user functions of LibTIDES.

Together with this tutorial, inside the directory `doc` of the TIDES distribution, you have a directory named `TIDESExamples` that contains the MATHEMATICA notebooks with the examples of the first part of the tutorial.

1.1 Differences of version 2.0 with respect to previous versions

> IT IS VERY IMPORTANT TO READ THIS SECTION IF YOU HAVE BEEN WORKING WITH PREVIOUS VERSIONS OF TIDES. DO NOT READ THIS SECTION IN OTHER CASE.

There are a lot of important differences between this version and previous versions. In fact, *the code generated with previous versions does not work with the new library* and *the code generated with this version is incompatible with the previous libraries*. Please rewrite all your codes before use them with TIDES 2.0.

The main differences of version 2.0 with respect to previous versions are the following:

- In previous versions of minc-tides (minf-tides) you compile the driver file and the ODE file together with the files `minc_tides.c` (`minf_tides.c`) written with Math-TIDES. In this version, by default, these files are not written, and you must compile the driver and the ODE file and link them with the library LibTIDES. If you prefer the old way to work, use the option `TIDESFiles` when you generate the driver and the ODE file (see 6.6 and 6.7).
- The ODE file generated in this version is incompatible with the ODE file generated in previous versions. Now it is independent of the partial derivatives that we compute. The code of a particular ODE changes only if we compute extra functions but it does not change if we compute partial derivatives.
- To compute a different set of partial derivatives we need to change only the driver.
- The data matrix to store the solution is initialized (with the correct dimensions) inside the integration function. The data type of this data matrix is a new C structure, different than in previous versions.
- In this version we may compute events (points where a function of the solution is zero or an extremum).

1.2 How to do ...?

If you want to learn how to do any particular action of TIDES follow the next links:

- How to install TIDES? : see chapter 4.
- General guidelines for using TIDES: see chapter 5.
- Differences among the four integrators of TIDES: see 3.2.

- How to load MathTIDES? : see 5.2.
- How to change the work directory in MathTIDES? : see 5.3.
- How to use the four integrators of TIDES?: see chapter 6.
- How to use minf-tides?: see 6.6.
- How to use minc-tides?: see 6.7.
- How to use dp-tides?: see 6.8.
- How to use mp-tides?: see 6.9.
- How to compile and run the files generated for each integrator?: see 6.6, 6.7, 6.8, 6.9.
- How to declare a first order differential equation (ODE)?: see (5.4 and 6.2), or (12.1 and 12.1.1).
- How to declare an ODE from a potential function?: see (5.4 and 7.1.1), or 12.1.3.
- How to declare an ODE from a Hamiltonian?: see (5.4 and 8.2.1), or 12.1.4.
- How to declare an ODE from a n-th order differential equation?: see (5.4 and 8.1.1), or 12.1.2.
- How to handle a non-autonomous ODE?: see 9.2.
- How to write code files to integrate an ODE (expression `TSMCodeFiles`)?: see 5.5 and 12.2.
- Options of `TSMCodeFiles`
  - `AbsoluteTolerance`: see 7.2 or *12.2.4.29*.
  - `AddFunctions` see *8.2.3.8* or *12.2.5.30*.
  - `AddPartials`: see *10.2.0.12* or *12.2.6.31*.
  - `CompensatedHorner`: see *12.2.9.47*.
  - `DataMatrix`: see (*8.2.4.9* and *11.2.2.20*), or *12.2.7.33*.
  - `DefectErrorControl`: see *12.2.9.44*.
  - `Driver`: see *9.5.0.10* or *12.2.3.21*.
  - `EventTolerance`: see *11.2.1.17* or *12.2.8.38*.
  - `EventsNumber`: see *11.2.1.18* or *12.2.8.39*.

  - `Factor1, Factor2, Factor3`: see *12.2.9.40*.
  - `FindExtrema`: see *11.2.1.14* or *12.2.8.35*.
  - `FindMaxima`: see *11.2.1.16* or *12.2.8.37*.
  - `FindMinima`: see *11.2.1.15* or *12.2.8.36*.
  - `FindZeros`: see *11.2.1.13* or *12.2.8.34*.
  - `InitialConditions`: see *6.5.0.4* or *12.2.4.26*.
  - `IntegrationPoints`: see (*7.4.0.7* and *11.2.2.19*), or *12.2.4.28*.
  - `KahanSummation`: see *12.2.9.46*.
  - `MaxIterationsNumber`: see *12.2.9.45*.
  - `MaxStepRatio`: see *12.2.9.41*.
  - `MinOrder`: see *12.2.9.42*.
  - `MinTIDES`: see *6.4.0.1* or *12.2.3.23*.
  - `MinStepRatio`: see *12.2.9.41*.
  - `ODEFiles`: see *9.5.0.11* or *12.2.3.22*.
  - `OrderIncrement`: see *12.2.9.43*.
  - `Output`: see *6.5.0.5* or *12.2.7.32*.
  - `ParametersValue`: see *7.1.1.6* or *12.2.4.27*.
  - `Precision`: see *6.4.0.2* or *12.2.3.24*.
  - `RelativeTolerance`: see 7.2 or *12.2.4.29*.
  - `TIDESFiles`: see *6.4.0.3* or *12.2.3.25*.

- A new expression of MathTIDES: `PartialDerivativesText`: 10.5 and 12.3.
- Understanding a simple driver: see 7.2.
- Understanding the code of an ODE function: see 7.3.
- How to use the LibTIDES functions to integrate an ODE?: see (7.5 and 9.4) or 13.2.
- How to use files as output?: see 8.1.2.
- How to handle data matrices with the solution?: see 8.2.4 or 13.5.
- How to compute a function of the solution?: see 8.2.1.
- How to use TIDES with multiple precision arithmetic?: see chapter 9.

- How to compute partial derivatives of the solution with respect to the initial conditions and the parameters?: see chapter 10.
- How to compute partial derivatives of functions of the solution with respect to the initial conditions and the parameters?: see chapter 10.
- How to compute the position of each partial derivative in TIDES output?: 10.6 or 13.3.
- What is an event?: see chapter 11.
- How to compute events?: see chapter 11.