ADMBase

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Abstract

Provides the basic ADM variables used in the $3+1$ formalism

1 Purpose

Thorn `ADMBase` provides core infrastructure for thorns implementing general relativity on a 3D grid in the $3+1$ formalism. It provides the basic variables (3-metric, extrinsic curvature, lapse and shift vector) for the $3+1$ formalism, in addition to a set of parameters to regulate the methods used for their evolution. These variables are used to communicate between thorns providing initial data, evolution methods and analysis routines for the $3+1$ formalism. In addition, the variables can be used as a mechanism to interact with alternative formalisms, as long as routines can be written to transform alternative variables into these $3+1$ variables.

2 Using ADMBase

2.1 3+1 Variables

The variables provided by `ADMBase` are:

- The 3-metric tensor, g_{ij}

  `gxx`, `gxy`, `gxz`,`gyy`, `gyz`,`gzz`
- The extrinsic curvature tensor, K_{ij}

  `kxx`, `kxy`, `kxz`,`kyy`,`kyz`,`kzz`
- The lapse function, α

  `alp`
- The (optional) shift vector β^i

  `betax`, `betay`,`betaz`

By default the metric and extrinsic curvature tensors are assumed to be *physical*, however these semantics can be changed by use of the `metric_type` parameter. `ADMBase` provides the default value of `physical`, however another thorn can extend this parameter, for example to specify that the variables `gxx` etc actually refer to the *conformal* 3-metric.

2.2 Initial Data

Initial data for the $3+1$ variables is specified by the `initial_data` (3-metric and extrinsic curvature), `initial_lapse` (lapse), and `initial_shift` (shift) parameters. By default, `ADMBase` initialises the 3-metric and extrinsic curvature to Minkowski and the lapse to one. Initial data thorns override these defaults by extending the parameters. To see which initial data sets are available in your executable run for example

```
./cactus_<config> -o admbase::initial_data | grep Range
```

The CactusEinstein arrangement includes thorns providing initial data for various black hole combinations, perturbed black holes and linear gravitational waves.

2.3 Evolution Methods

Analogous to specifying initial data, evolution methods are chosen by the `evolution_method` (3-metric and extrinsic curvature), `lapse_evolution_method` (lapse), and `shift_evolution_method` (shift) parameters. By default, `ADMBase` does not evolve the 3-metric or extrinsic curvature, and holds the lapse and shift static.

3 Programming With ADMBase

3.1 3+1 Variables

It is highly recommended that all thorns which inherit from ADMBase check the value of the `metric_type` parameter in a routine scheduled at `CCTK_PARAMCHECK` and signal an error if the metric type is not recognised. (See the source file `ParamCheck.c` in any of the thorns in the `CactusEinstein` arrangement for examples of this, and note that the `PARAMCHECK` time bin is a good place to check for illegal/bad combinations of parameters, and also to inform the user of any relevent details of the parameters she has chosen).

ADMBase allocates one timelevel of memory for all variables, except the shift, which is only allocated if the `initial_shift` parameter is set to a value other than 'none'. ('none' is the default.) The state of the shift storage is indicated by the `shift_state` grid scalar. This is 1 if there is storage for the shift, and 0 otherwise.

The thorn provides, on request, initial data to set the metric and extrinsic curvature to flat space in cartesian coordinates, to set the initial lapse to one and the initial shift to zero.

3.2 Initial Data

To include your initial data sets for the 3-metric, extrinsic curvature, lapse and shift in the `ADMBase` infrastructure, extend the keyword parameters `initial_data`, `initial_lapse` and `initial_shift`. For example, in the `param.ccl` file of `CactusEinstein/IDAnalyticBH`,

```
shares: ADMBase

EXTENDS KEYWORD initial_data
{
  "schwarzschild"      :: "One Schwarzshild black hole"
  "bl_bh"              :: "Brill Lindquist black holes"
  "misner_bh"          :: "Misner black holes"
  "multiple_misner_bh" :: "Multiple Misner black holes"
  "kerr"        :: "One Kerr black hole"
}
```

`ADMBase` also schedules two groups `ADMBase_InitialData` and `ADMBase_InitialGauge` in this order at `CCTK_INITIAL`. Initial data and initial gauge thorns should schedule their routines to run in this group, for example

```
if (CCTK_Equals(initial_data,"schwarzschild"))
{
   schedule Schwarzschild in ADMBase_InitialData
   {
     LANG: C
   } "Construct initial data for a single Schwarzschild black hole"
}
```

ADMBase also schedules a group ADMBase_PostInitial at CCTK_INITIAL after both ADMBase_InitialData and ADMBase_InitialGauge. This group is meant for thorns that modify the initial data, such as e.g. adding noise to an exact solution.

4 Shift Vector

It is only relatively recently that numerical relativists have started to use a shift vector in 3D calculations, and previously, to save space, storage for the shift vector was not allocated. If the parameter initial_shift is set to none, ADMBase does not allocate storage for betax, betay, betaz and sets the grid scalar shift_state to 0. In all other cases the shift_state parameter is set to 1.

Thorns using the shift should always check that storage for the shift is allocated before using it.