An efficient implementation of an adaptive and parallel grid in DUNE

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Summary. In this contribution we describe and evaluate an efficient implementation of an adaptive and parallel grid (ALUGrid) within the Distributed and Unified Numerics Environment DUNE. A generalization of the serial grid interface of DUNE, described in [1], to the adaptive and parallel case is discussed and example computations using the grid interface are presented. The computations are compared with computations of the original code, which was optimized for the specific example problem studied here.

1 Introduction

In [1] a serial version of a generic grid interface was introduced that was realized within the Distributed and Unified Numerics Environment DUNE. One of the major goals of such an interface based numerics environment is the separation of data structures and algorithms. For instance, the problem implementation can be done on the basis of the interface independent of the data structure that is used for a specific application. Moreover such a concept allows a reuse of existing codes beyond the interface. Up to now, within DUNE, there are five implementations of the grid interface, for example the interface implementation for the PDE software toolbox UG [2], for the Finite Element toolbox ALBERTA [3], and an implementation for a structured grid. Some of these implementations can be used to perform parallel computations. In this paper we focus on the detailed description of the parallel part of the grid interface that provides the necessary functionality for parallel computations. As some of the packages are already endowed with a parallelisation concept, the interface has to support an efficient access to
the already existing parallelisation concepts. In this contribution we focus on
the description of an efficient implementation of the parallel interface for the
adaptive and parallel ALUGrid library [4, 5]. ALUGrid is an adaptive, load
balanced, unstructured grid implementation that was specifically designed
for an efficient implementation of explicit finite volume schemes for nonlin-
ear conservation laws. The goal of this contribution is to demonstrate that
the parallel grid interface to ALUGrid can be implemented in such an effi-
cient way that the resulting adaptive and parallel computations based on the
implementation in DUNE are competitive with computations of the original
finite volume code in ALUGrid.

The paper is organized as follows: in Section 2 we give an abstract def-
ition of a parallel hierarchic grid and discuss the corresponding interface
classes in DUNE. In addition, the specific features of the ALUGrid library are
discussed. In Section 3 the handling of arbitrary data during grid reorganiza-
tion in the case of grid adaptation and dynamic load balancing is discussed
and an efficient implementation is presented that avoids the usage of virtual
functions in C++. Finally, in Section 4 a run time comparison between the
original finite volume implementation in ALUGrid and the interface based
implementation in DUNE is given.

2 Design of the parallel Grid Interface

The DUNE grid interface is an interface for parallel grids. This means that a
serial grid can be seen as a parallel grid which runs on one processor. There-
fore the described functionality is provided by every grid implementing the
interface and for some implementations, methods such as loadBalance just do
nothing. This guarantees that code written for parallel applications can be
used for serial calculations as well. Furthermore the part of the grid interface
responsible for parallelisation should be such that the user can write code
for parallel applications without much effort, i.e. without coding MPI com-
mands. The intention of the design is to provide a parallel extension of the
grid interface by adding only a minimum number of methods.

This section is split into three parts: first an abstract mathematical defi-
nition of the parallel extension of the DUNE grid is presented. Then in the
second part the classes implementing the abstract definitions are described.
The last part describes the features of the ALUGrid library concerning the
grid and the interpretation of the features in terms of the abstract definition
of the DUNE grid interface.

2.1 Abstract definition of the parallel grid

In the following we define a grid $T$ in mathematical terms. It is supposed
to discretize a domain $\Omega \subset \mathbb{R}^n$, $n \in \mathbb{N}$, $n > 0$, with piecewise smooth
boundary $\partial \Omega$. A grid $T$ consists of $L + 1$ grid levels