Exploring techniques for practical performance modelling

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Motivation

1. Many large scientific models including the UM have run-time options such as the domain decomposition, number of OpenMP threads, and the number and placement of MPI tasks. These choices can dramatically alter performance.

2. In the climate modelling community, the lifecycle of the machine is far longer than the application, so we want a method of modelling that can be quickly applied to a new machine.

Performance models

A performance model predicts how long an application will take to run on a computer system. This is useful when the application or computer does not exist, or when measuring directly would take too long.

In our definition, performance models consist of an application part, which describes the amount and type of work to be performed, and a corresponding machine part that provides times to complete each portion of work. The machine is split into two components: i) the processor which handles floating point calculations and ii) the network which handles MPI data transfers between processors.

Analytical application models

- Empirical and profile-based models are generated from run-time measurement and contain no information about the structure of the application. Factoring out deployment parameters requires complex statistical methods.
- Analytical models are built around parameters that affect performance. This requires detailed knowledge of the code but provides the most flexible models. Analytical models can be fed run times from different types of machine models (theoretical, empirical or semi-empirical/semi-analytical).

Theoretical machine models

Modelling from first principles is possible for some simple architectures, but has become more impractical with the increase in complexity of modern hardware.

The figure below shows the predicted peak performance based on instruction counts for 3 different K10 Opter series processors. The method was found to break down for the later Bulldozer Opteron series.

Empirical machine models

Due to the complexity of the modern architecture, even theoretical models require some level of accuracy. We have found that empirical methods based on bespoke-benchmarks work best. For example, in a halo exchange of 2-dimensional fabric of data, one of the buffers comes from data stored non-contiguously, and standard MPI benchmarks do not account for these data access times.

The figure below shows communication time for different MPI rank to core mapping strategies using data from a bespoke benchmark. Although the run times are not always accurate, the best choice of placement is clear.

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