Programming with Parallel Objects

Session 3: Advanced Programming with Charm++

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ADMINISTRATIVIA

- Official Charm++ website:
  http://www.charmplusplus.org/
- Slides and code for this tutorial:
  https://github.com/emenesesrojas/parallel_objects.git
- Questions on parallel objects programming:
  https://ecar2017.slack.com
- Advanced questions on Charm++:
  ppl@cs.illinois.edu
- Official instructor's email address:
  emeneses@cenat.ac.cr

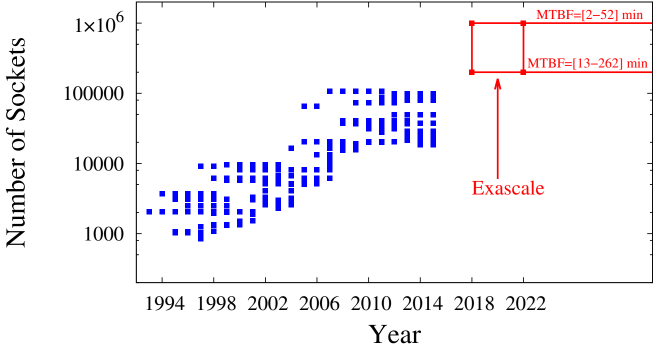
Outline

Checkpointing and Resilience

Performance Analysis

The Reliability Problem

Future supercomputers will fail frequently

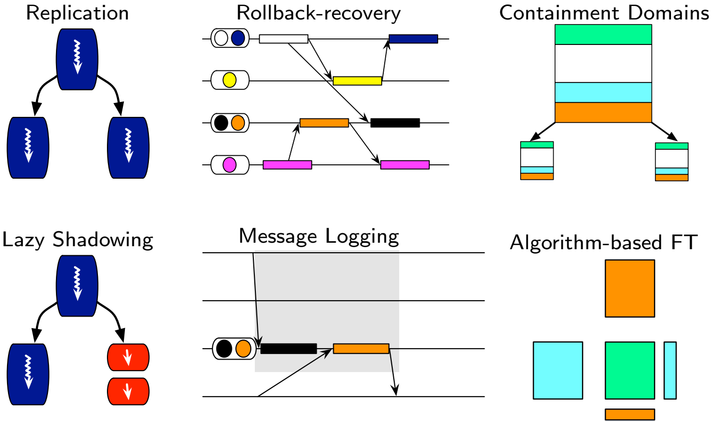


Source: www.top500.org

- *Today, more than 20% of the computing capacity in a large HPC system is wasted due to failures and recoveries* [Elnozahy, 2010]
- *There were 317 independent hardware failures on Titan in 2014* [Meneses, 2015]
- *Insufficient resilience of the software infrastructure would likely render extreme scale systems effectively unusable* [Dongarra, 2011]

The Current Solution

Several strategies make supercomputing reliable



More transparent...Less transparent

Fault Tolerance in Charm++

Approaches based on migratability

- Four Approaches:
  - Disk-based checkpoint/restart
  - In-memory double checkpoint/restart
  - (experimental) Proactive object evacuation
  - (experimental) Message-logging for scalable fault tolerance
- Common Features:
  - Easy checkpoint
  - Migrate-to-disk leverages object-migration capabilities
  - Based on dynamic runtime capabilities
  - Can be used in concert with load-balancing schemes

Split Execution

Checkpointing to the file system

- The common form of checkpointing
  - The job runs for 5 hours, then will continue at the next allocation another day!
- The existing Charm++ infrastructure for chare migration helps
- Just "migrate" chares to disk
- The call to checkpoint the application is made in the main chare at a synchronization point
- Example:

```
CkCallback cb(CkIndex_Hello::SayHi(),helloProxy);
CkStartCheckpoint(''log'',cb);
```

Split Execution

Additional changes to code

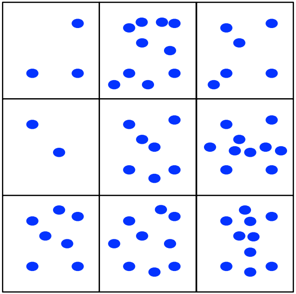
- Main chare must be made migratable
- Groups must be made migratable
- Migratable objects have both, a `pup` method and a migration constructor
- Resuming execution:

```
> ./charmrun hello +p4 +restart log
```

Exercise 3.1

Particle interaction

Add checkpointing capabilities to the particle interaction code on a 2D space:



Complete the code in directory:

`code/particle/skeleton`

of the class repository:

`git clone https://github.com/emenesesrojas/parallel_objects.git`

Do not forget to define variable `CHARMDIR` in the Makefile

Performance Analysis

Using Projections to find bottlenecks

- Instrumentation and measurement
  - Link program with `-tracemode projections` or `-tracemode summary`
  - Trace data is generated automatically during run
  - User events can be easily inserted as needed
- Projections: visualization and analysis
  - Scalable tool to analyze up to 300,000 log files
  - A rich set of tool features: time profile, time lines, usage profile, histogram, and more
  - Detect performance problems: load imbalance, grain size, communication bottleneck, and more

Using Projections

Different types of tools

- Tools of aggregated performance viewing
  - Time profile
  - Histogram
  - Communication over time
- Tools of processor level granularity
  - Overview
  - Timeline
- Tools of derived/processed data
  - Extrema analysis: identifies outliers
  - Noise miner: highlights probable interference

Problem Identification

Procedure

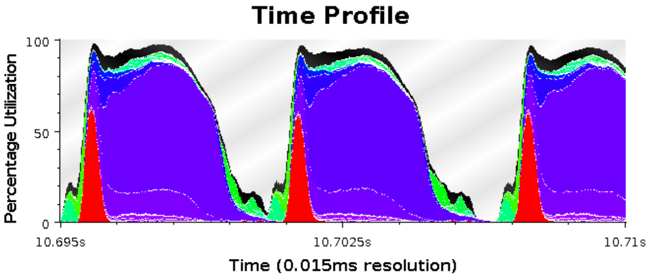
- Load imbalance
  - Time profile: lower CPU usage
  - Extrema analysis tool:
    - Least idle processors
  - Load the over-loaded processors in Timeline
  - Histogram: grain size issues

Example
NAMD

- Molecular dynamics:
  - Trying to identify the next performance obstacle for NAMD
    - Running on 8192 processors, with 1 million atom simulation
    - Jaguar Cray XK6
    - Test scenario: with PME every step

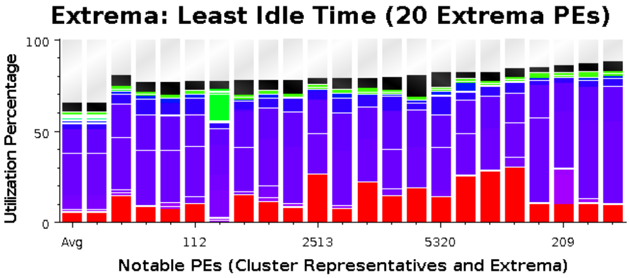
Example

Time profile



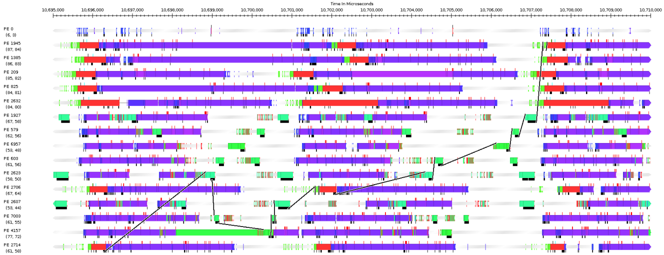
Example

Extrema tool for least idle processors



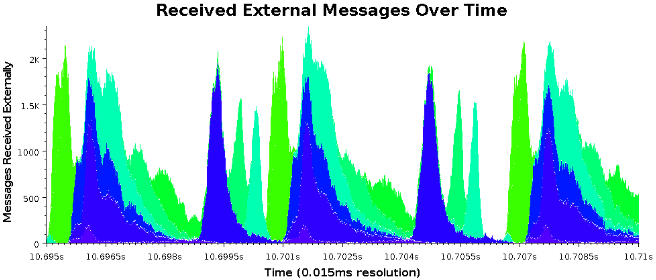
Example

Time lines with message back tracing



Example

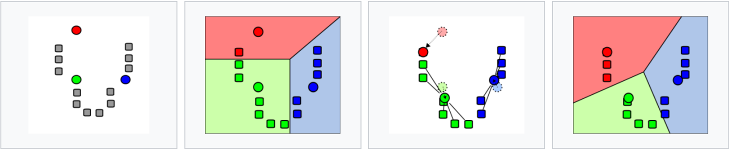
Communication over time for all processors



Project

Parallel K-means

Write a Charm++ parallel program to solve k-means on an *n*-dimensional space:



Complete the code in directory:

`code/kmeans/skeleton`

of the class repository:

`git clone https://github.com/emenesesrojas/parallel_objects.git`

Do not forget to define variable `CHARMDIR` in the Makefile

Project
Specifications

- Data points must be randomly created inside a unit multidimensional cube
- There must be a 1D array of parallel objects
- Each object holds a portion of the data points and computes the clustering
- The last object of the array has at least 10 times more data points than the rest
- Migration of objects must be implemented
- The main chare collects the new computed centers every iteration
- Turn in this project individually
- Send the solution to `emeneses@cenat.ac.cr`

Concluding Remarks

- Reliability is a fundamental concern in making usable supercomputers
- Migratability empowers fault tolerance in Charm++
- Performance analysis is a useful tool to detect performance bottlenecks

Thank You!
Q&A

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