A Practical Guide to Amelia: A Domain Specific Language for Automated Software Deployment

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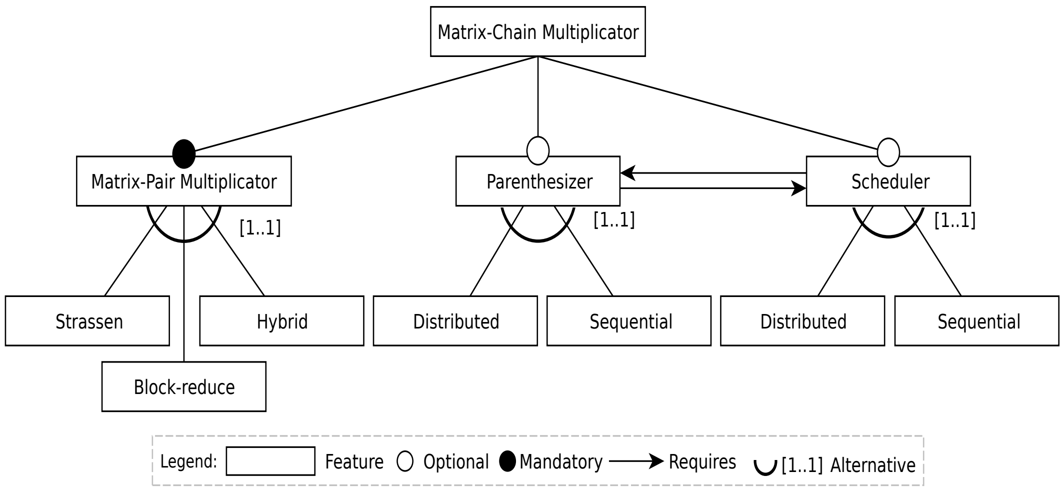
1 Introduction

To facilitate and promote the use of the Amelia DSL, our language that assists application developers in automating the deployment of component-based software systems, we designed a deployment case study to use the main features of Amelia. Through this practical guide, a *software deployer* will be able to get a deeper understanding of the constructs defined in Amelia, which will increase the deployer's ability for specifying the required deployment specifications with the language.

2 Case Study: The Matrix-Chain Multiplication Problem

The Matrix-Chain Multiplication (MCM) problem is an optimization problem that consists in finding the most efficient multiplication sequence to multiply a set of given matrices. Our implementation of the MCM, provided to the workshop participants, splits the problem into three different subproblems: the matrix-pair multiplication problem, the matrix-chain parenthesization problem, which finds the optimal sequence of matrix-pair multiplications minimizing the number of individual additions and multiplications, and the matrix-subchain multiplication scheduling problem, which finds subsets of matrix multiplications that can be performed concurrently to decrease the overall multiplication time [1]. In this way, by combining the different solutions to these subproblems, it is possible to configure several different actual solutions to the whole problem, which raises a problem of solution configuration. For instance, by combining the first and second subproblems, one can obtain a solution able to multiply a set of given matrices reducing the number of individual arithmetical operations. In the same sense, by combining the first and third subproblems, one would obtain the same solution aforementioned, but this time reducing multiplication time. And of course, by combining the three subproblems one would reduce both operations and overall processing time. In practice, however, there can be computational limitations and trade-offs that may make infeasible some of the possible solution configurations.



In this implementation of the MCM solution, we take advantage of distributed computational resources in order to reduce the execution time when multiplying a large number of considerably big matrices. To this end, we developed two multiplication strategies, one based on the map-reduce architecture, and a variation of it that significantly reduces network usage. At the end, local multiplications are performed using the Strassen algorithm.

The following deployment diagrams depict the high-level elements composing each of the multiplication strategies. For sake of simplicity, we omit the details of the scheduling and parenthesizing subproblems. As there is only one artifact per strategy (*i.e.*, one resulting artifact of the compilation process), a note on each diagram specifies the node in which the components are executed.

2.1 BlockReduce Strategy

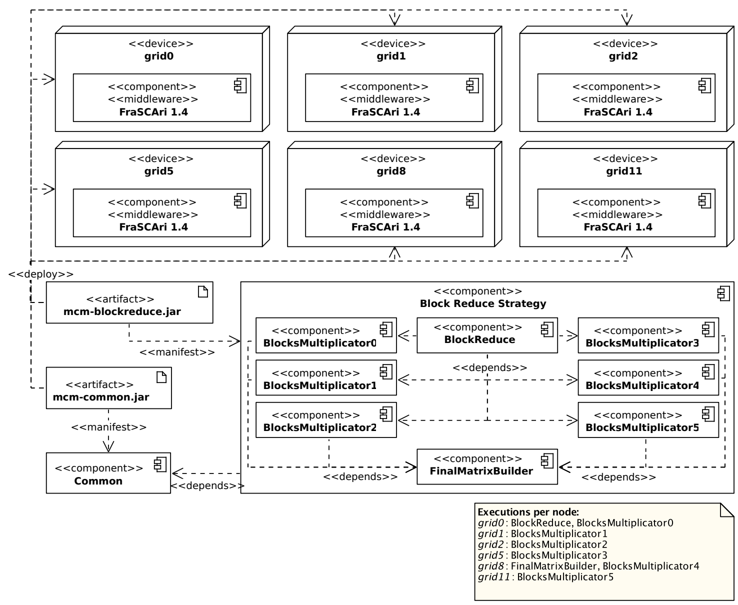


Figure 1: Deployment Diagram for the BlockReduce Configuration Strategy

The BlockReduce consiguration strategy consists in splitting each matrix into fixed-size blocks (*i.e.*, sub-matrices) and multiply them as if they were one cell instead of a group of them. For instance, having two squared matrices A and B, partitioned into 4 blocks each, the resulting matrix C would be calculated using the same blocks partition strategy. C_{00} represents the first block of C, and would be calculated by operating A and B such that $C_{00} = A_{00} * B_{00} + A_{01} * B_{10} + A_{02} * B_{20} + A_{03} * B_{30}$. In this strategy, the block size is crucial to find the threshold between the amount of data transmitted over the network and the size of the blocks to multiply, in order to reduce the multiplication time. We performed several experiments and found that for matrices of approximately 3600x3600 elements, the block size with best execution times is 200.

2.2 Hybrid Configuration Strategy

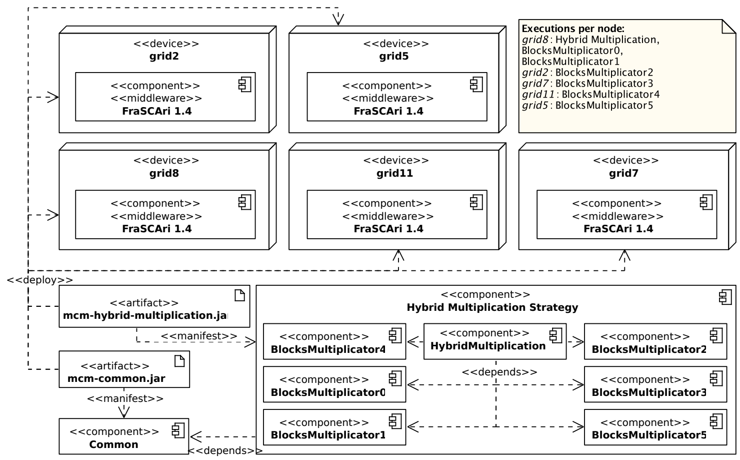


Figure 2: Deployment Diagram for the Hybrid Configuration Strategy

The Hybrid configuration strategy introduces an improvement, in terms of network usage, to the BlockReduce configuration strategy. However, it is more demanding in terms of processor and memory usage. In the strategy above, calculating a block in the resulting matrix requires sending as many pairs of blocks as columns or rows of blocks are, while in this strategy it only requires sending the whole column and row of blocks. Another advantage of this strategy is that it also reduces the amount of processors necessary to multiply the blocks.

3 The Amelia Language: Specification Examples

Amelia allows specifying two types of elements: Subsystems and Deployments. Along with this practical guide you will be given an overview of the language syntax and the associated semantics. The following examples describe two deployment requirements and their corresponding solution in Amelia.

3.1 Requirement 1 (Example)

Specify the deployment of the BlockReduce strategy having into account component dependencies and the computing nodes specified in the deployment diagram. You may use the following file containing a mapping between the hosts in the deployment diagrams and the laboratory's computers.

```
hgrid1    21 22 root  liasondriso_hgrid1   grid0
hgrid17   21 22 root  liasondriso_hgrid2   grid1
```

```
hgrid16   21  22  root   liasondriso_hgrid3    grid2
hgrid15   21  22  root   liasondriso_hgrid4    grid3
hgrid12   21  22  root   liasondriso_hgrid5    grid4
hgrid9    21  22  root   liasondriso_hgrid6    grid5
hgrid6    21  22  root   liasondriso_hgrid7    grid6
hgrid10   21  22  root   liasondriso_hgrid10   grid7
```

Listing 1: hosts.txt

```
package co.edu.icesi.driso.matrices

import java.util.List
import java.util.Map
import org.amelia.dsl.lib.descriptors.Host

/*
 * Common definitions for all of the deployments/subsystems.
 */
subsystem Common {

   /*
    * All hosts.
    */
   param Map<String, Host> hosts

   //------------------------------------------------------------------------
   // Compilation parameters
   //------------------------------------------------------------------------

   /*
    * Compilation host.
    */
   var Host compilationHost = hosts.get("grid0");

   /*
    * Sources to compile.
    */
   var String commonSources = "/home/sas1/LF_RIVERA/workspace-matrices/org.driso.matrices.common";
   var String blockRSources = "/home/sas1/LF_RIVERA/workspace-matrices/org.driso.matrices.blockreduce";
   var String hybridSources = "/home/sas1/LF_RIVERA/workspace-matrices/org.driso.matrices.hybrid_multipli
   var String nMatricesSources = "/home/sas1/LF_RIVERA/workspace-matrices/org.driso.matrices.nmatrices";
   var String strassenSources = "/home/sas1/LF_RIVERA/workspace-matrices/org.driso.matrices.strassen";

   /*
```

```
     * Compilation sources.
     */
    var List<String> sources = #[
        commonSources, blockRSources, hybridSources,
            nMatricesSources,
        strassenSources
    ]

    /*
     * Built sources folder (The site where compilation
         artifacts are located).
     */
    var String builtFolder =
        "/home/sas1/LF_RIVERA/workspace-matrices/built-sources";

    //------------------------------------------------------------------------
    // Allocation parameters
    //------------------------------------------------------------------------

    /*
     * The folder in the execution nodes where artifacts
         are allocated.
     */
    var String allocationTargetFolder = "/home/sas1/";

    /*
     * Target sources folder in the execution nodes
     * (The site where the jars are executed).
     */
    var String builtsFolder =
        'allocationTargetFolderbuilt-sources';
}
```

Listing 2: Subsystem Common

```
package co.edu.icesi.driso.matrices

import co.edu.icesi.driso.matrices.classes.Strategy

includes co.edu.icesi.driso.matrices.Common

/*
 * Compile each strategy's source code.
 */
subsystem Compile {
    /*
     * The multiplication strategy to compile.
     */
    param Strategy strategy

```

```
    on compilationHost {
       compileCommon:
          cd sources.get(0)
          compile "src" "mcm-common"
          cmd 'yes | cp -f mcm-common.jar builtFolder/'
    }

    on compilationHost ? strategy ==
        Strategy.BLOCK_REDUCE {
       strategy1: compileCommon;
          cd sources.get(1)
          compile "src" "mcm-blockreduce" -classpath
              'builtFolder/mcm-common.jar'
          cmd 'yes | cp -f mcm-blockreduce.jar
              builtFolder'
    }

    on compilationHost ? strategy ==
        Strategy.HYBRID_MULTIPLICATION {
       strategy2: compileCommon;
          cd sources.get(2)
          compile "src" "mcm-hybrid-multiplication"
              -classpath 'builtFolder/mcm-common.jar'
          cmd 'yes | cp -f mcm-hybrid-multiplication.jar
              builtFolder'
    }

    on compilationHost ? strategy == Strategy.N_MATRICES {
       strategy3: compileCommon;
          cd sources.get(3)
          compile "src" "mcm-nmatrices" -classpath
              'builtFolder/mcm-common.jar'
          cmd 'yes | cp -f mcm-nmatrices.jar builtFolder'
    }

    on compilationHost ? strategy == Strategy.STRASSEN {
       strategy4: compileCommon;
          cd sources.get(4)
          compile "src" "mcm-strassen" -classpath
              'builtFolder/mcm-common.jar'
          cmd 'yes | cp -f mcm-strassen.jar builtFolder'
    }

}
```

Listing 3: Subsystem for compiling the source code

```
package co.edu.icesi.driso.matrices.classes;

import java.io.IOException;
```

```java
import org.amelia.dsl.lib.CallableTask;
import org.amelia.dsl.lib.descriptors.CommandDescriptor;
import org.amelia.dsl.lib.descriptors.Host;
import net.sf.expectit.Expect;
import net.sf.expectit.matcher.Matchers;

public class SCPLogin {

   public static CommandDescriptor scpCommand(final
       String hostName,
       final String hostPassword, final String source,
           final String target) {
      return new CommandDescriptor.Builder()
          .withSuccessMessage("Copied file!")
         .withErrorMessage("File couldn't be copied!")
         .withCallable(new CallableTask<Object>() {
            @Override
            public Boolean call(Host host, String
                prompt, boolean quiet)
                throws Exception {
               final Expect session =
                  host.ssh().expect();
               session.sendLine(
                   String.format(
                       "scp -r root@%s:%s %s",
                       hostName,
                       source,
                       target
                   )
               );
               try {
                  session.expect(
                      Matchers.regexp("Are you sure you
                          want to continue connecting
                          (yes/no)?")
                  );
                  session.sendLine("yes");
               } catch (IOException e) {
                   // Do nothing
               }
               session.expect(
                   Matchers.regexp(
                       String.format(
                           "root@%s's password:",
                           hostName
                       )
                   )
               );
               session.sendLine(hostPassword);
               session.expect(Matchers.regexp(prompt));
```

```
                return true;
            }
        }).build();
    }

}
```

Listing 4: Class for scp

```
package co.edu.icesi.driso.matrices

import co.edu.icesi.driso.matrices.classes.SCPLogin
import java.util.List
import org.amelia.dsl.lib.descriptors.Host

includes co.edu.icesi.driso.matrices.Common

depends on co.edu.icesi.driso.matrices.Compile

subsystem Allocation {

    param List<Host> executionHosts

    on executionHosts {
        move:
            SCPLogin.scpCommand(
                    compilationHost.hostname,
                    compilationHost.password,
                    builtFolder,
                    allocationTargetFolder
            )
    }

}
```

Listing 5: Subsystem for allocation

```
package co.edu.icesi.driso.matrices

import java.util.List
import org.amelia.dsl.lib.descriptors.Host

includes co.edu.icesi.driso.matrices.Common

depends on co.edu.icesi.driso.matrices.Allocation

/*
 * Execute the BlockReduce multiplication strategy.
 */
subsystem BlockReduce {
```

```

param List<Host> executionHosts

var String common = "mcm-common"
var String artifact = "mcm-blockreduce"
var Iterable<String> libpath = #[
 'builtsFolder/common.jar',
 'builtsFolder/artifact.jar'
]

on executionHosts {
   init:
         cd builtsFolder
}

on hosts.get("grid1") {
   reducer0: matrixBuilder;
      run "BlocksMultiplicator0" -libpath libpath

   control: reducer0, reducer1, reducer2, reducer3, reducer4, reducer5;
      run "Blockreduce" -libpath libpath
}

on hosts.get("grid2") {
   reducer1: matrixBuilder;
      run "BlocksMultiplicator1" -libpath libpath
}

on hosts.get("grid3") {
   reducer2: matrixBuilder;
      run "BlocksMultiplicator2" -libpath libpath
}

on hosts.get("grid4") {
   reducer3: matrixBuilder;
      run "BlocksMultiplicator3" -libpath libpath
}

on hosts.get("grid5") {
   matrixBuilder: init;
      run "FinalMatrixBuilder" -libpath libpath

   reducer4: matrixBuilder;
      run "BlocksMultiplicator4" -libpath libpath
}

on hosts.get("grid6") {
   reducer5: matrixBuilder;
      run "BlocksMultiplicator5" -libpath libpath
```

```
    }

}
```

Listing 6: Subsystem for BlockReduce

```
package co.edu.icesi.driso.matrices

includes co.edu.icesi.driso.matrices.Common

depends on co.edu.icesi.driso.matrices.Allocation

/*
 * Execute the Hybrid multiplication strategy.
 */
subsystem HybridMultiplication {

    var String common = "mcm-common"
    var String artifact = "mcm-hybrid-multiplication"
    var Iterable<String> libpath = #[
         'builtsFolder/artifact.jar',
         'builtsFolder/common.jar'
    ]

     on hosts.get("grid5") {
         reducer0:
          run "BlocksMultiplicator0" -libpath libpath

         reducer1:
          run "BlocksMultiplicator1" -libpath libpath

         control: reducer0, reducer1, reducer2, reducer3,
             reducer4, reducer5;
          run "HybridMultiplication" -libpath libpath
    }

    on hosts.get("grid3") {
       reducer2:
          run "BlocksMultiplicator2" -libpath libpath
    }

    on hosts.get("grid7") {
       reducer3:
          run "BlocksMultiplicator3" -libpath libpath
    }

    on hosts.get("grid6") {
       reducer4:
          run "BlocksMultiplicator4" -libpath libpath
    }
```

```

   on hosts.get("grid4") {
      reducer5:
         run "BlocksMultiplicator5" -libpath libpath
   }

}
```

Listing 7: Subsystem for Hybrid

```
package co.edu.icesi.driso.matrices.classes;

/**
 * The mcm strategies.
 * @author Miguel Jimenez (miguel@uvic.ca)
 * @date 2017-08-19
 * @version $Id$
 * @since 0.0.1
 */
public enum Strategy {
    BLOCK_REDUCE,
    HYBRID_MULTIPLICATION,
    N_MATRICES,
    STRASSEN
}
```

Listing 8: Enum

```
package co.edu.icesi.driso.matrices.deployments

import co.edu.icesi.driso.matrices.classes.Strategy
import java.util.List
import java.util.Map
import org.amelia.dsl.lib.descriptors.Host
import org.amelia.dsl.lib.util.Hosts

includes co.edu.icesi.driso.matrices.Common
includes co.edu.icesi.driso.matrices.Compile
includes co.edu.icesi.driso.matrices.Allocation
includes co.edu.icesi.driso.matrices.BlockReduce

/*
 * Deploy the BlockReduce strategy once and then
 * stop the executed components.
 */
deployment SimpleBlockReduce {
   // Load all hosts and then filter
   val Map<String, Host> hosts =
       Hosts.hosts("hosts.txt").toMap[h|h.identifier]
   val List<Host> executionHosts = #[
```

```
        hosts.get("grid1"), hosts.get("grid2"),
            hosts.get("grid3"),
        hosts.get("grid4"), hosts.get("grid5"),
            hosts.get("grid6")
    ]

    // Add subsystems to deploy
    add(new Common(hosts))
    add(new Compile(Strategy.BLOCK_REDUCE, hosts))
    add(new Allocation(executionHosts, hosts))
    add(new BlockReduce(executionHosts, hosts))

    // Deploy and then stop the executed components
    start(true)
}
```

Listing 9: Deployment for BlockReduce

```
package co.edu.icesi.driso.matrices.deployments

import co.edu.icesi.driso.matrices.classes.Strategy
import java.util.List
import java.util.Map
import org.amelia.dsl.lib.descriptors.Host
import org.amelia.dsl.lib.util.Hosts

includes co.edu.icesi.driso.matrices.Common
includes co.edu.icesi.driso.matrices.Compile
includes co.edu.icesi.driso.matrices.Allocation
includes co.edu.icesi.driso.matrices.HybridMultiplication

/*
 * Deploy the HybridMultiplication strategy once and then
 * stop the executed components.
 */
deployment SimpleHybridMultiplication {
    // Load all hosts and then filter
    val Map<String, Host> hosts =
        Hosts.hosts("hosts.txt").toMap[h|h.identifier]
    val List<Host> executionHosts = #[
        hosts.get("grid3"), hosts.get("grid4"),
            hosts.get("grid5"),
        hosts.get("grid6"), hosts.get("grid7")
    ]

    // Add subsystems to deploy
    add(new Common(hosts))
    add(new Compile(Strategy.HYBRID_MULTIPLICATION,
        hosts))
    add(new Allocation(executionHosts, hosts))
```

```
    add(new HybridMultiplication(hosts))

    // Deploy and then stop the executed components
    start(true)
}
```

Listing 10: Deployment for Hybrid

References

[1] H. Lee, J. Kim, S. J. Hong, and S. Lee. Processor allocation and task scheduling of matrix chain products on parallel systems. *IEEE Transactions on Parallel and Distributed Systems*, 14(4):394–407, April 2003.