Lafros MaCS: an experimental Scala monitoring and control API

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ABSTRACT

Lafros MaCS is a layer of software designed for use in distributed monitoring and control applications. Written in the hybrid object-functional and statically-typed Scala language, it is the successor of JMaCS, written in Java, making it also a descendent of experimental software first developed for the ESR. It will be shown how Scala makes possible full type safety, together with more elegant programmable-device definitions.

Keywords: software, monitor, control, API, distributed, remote, GUI, Scala, MaCS

1. INTRODUCTION

The Lafros Monitoring and Control System (MaCS) software[1] is an API written in the Scala[2][1] programming language, designed to help facilitate the local or remote, interactive and programmatic, monitoring and control of a distributed target in soft[3] realtime. It does not provide all these facilities by itself, but rather defines a standard way to plug abstract devices into an abstract system that may be implemented by a third party.

MaCS is essentially a complete rewrite of an existing Java API, JMaCS[4][2], in Scala. We therefore begin with a brief review of JMaCS and its programmable devices (PDs), before pointing out some of that API's known weaknesses. This is then followed by a brief introduction to Scala. After first mentioning some of the details of moving the development from Java to Scala, and discussing the use of Scala idioms, the two APIs are then compared, in terms of the code required to define, deploy and program an example PD. Some conclusions about the merits of MaCS and Scala relative to JMaCS and Java are then drawn.

2. MOTIVATION

2.1 JMaCS

Derived from experimental software[3][4] first developed for the ESR, JMaCS sets out to exploit the full potential of an all-Java system of distributed objects (as opposed to a heterogeneous one). In particular, such a system is not restricted to exchanging passive data (such as text or documents), but may exchange Java objects themselves, and in an efficient, secure and object-oriented[5] way. Thus, using JMaCS,

- an instance of a Java class representing a command or PD program can be created and configured in a user interface (UI)-client object, and sent to a device interface (DI)-client one, with full propagation of any exception thrown in the latter; DI clients may also send such objects to each other;
- instances of a Java class representing status samples are created in the DI-client object, and sent to UI client and other DI-client ones;
- a Java class representing a monitor or control-panel GUI is named in the DI-client object, for subsequent instantiation and use in UI-client ones.

One of JMaCS's central concepts is the PD: a reusable definition of a device, complete with monitor and control-panel GUIs, command interpreter, and API (whose implementation may be separate and in hardware). Thus, it is usually more

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1 http://lafros.com/macs
2 http://scala-lang.org
3 See [2] and references therein.
4 http://jmacs.org
5 This refers to the remote polymorphism supported by Java's Remote-Method Invocation (RMI) infrastructure – see [2] and references therein.

convenient to implement a PD, and create a DI-client object from that, rather than implement a DI driver plug-in directly. In addition to being reusable, in the definition of other PDs as well as the creation of DIs, PDs are also programmable.

It is therefore desirable to be able to write PD definitions as concisely and with as much type-safety[6] as possible, and for them to be convenient to use as components. Those written to the current[7] JMaCS API have the following weaknesses in the above respects:

- the name of each PD is that of its package; however, it is necessary to duplicate the rightmost portion of this when naming the container class that is required;
- the container class's `IConstants`, `IDriver` and `IStatus` interfaces must extend respective tag interfaces, which is somewhat verbose;
- a proxy class has to be defined, but supplies no additional information about the PD's API;
- the `Interpreter` and `MonitorGui` classes, and all program ones are not fully type-safe, being passed arguments having tag interface types (or type `Object`), which must be cast to the appropriate PD ones.

It was with the above in mind that consideration was given to rewriting JMaCS in a new language.

2.2 Scala

It is no longer the case that programs targeting the Java platform must be written in the Java language, and among the alternatives is Scala. Apart from its being statically-typed[8] and fully interoperable with Java, the following attributes were what first made this one appealing:

- better support for writing components (such as PDs), thanks to a form of multiple implementation inheritance involving traits;
- tighter and more concise syntax, thanks to its implicitly final method-parameters, and type inference;
- support for an alternative style of concurrency (to that based on Java's synchronized blocks), in the form of actors.

However, Scala soon turned out to have other attractions:

- a novel combination of features in support of writing fully type-safe code: inner-classes, type members, singleton objects, and the ability to override the type of the self reference;
- extensibility through libraries (rather than adding to the language itself), made possible in large part by the fact that all values are objects, and all operators are methods;
- full support for functional programming and closures: besides methods, functions may be defined as values of function types;
- utility also as a scripting language[9].

3. METHOD

3.1 Development notes

Compilation of Scala source files produces regular Java .class files, that may be packaged as regular .jar files. However,

- the Scala library .jar file is required in the classpath, for execution[10];
- applications require their entry point to be a `def main(args: Array[String]) {…}`, residing in a singleton object.

No significant changes were therefore required in order to switch to developing MaCS. Note, however, that special measures[11] will be required when developing downloadable apps, to avoid downloading the entire Scala library as well.

6 a property of statically-typed languages, enforced by the compiler
7 version 3.3.1
8 the types of variables being fixed when they are declared
9 'Scala' is a contraction of 'scalable language', reflecting the intention that it should be applicable for writing small programs as well as large ones.
10 including that of the scala compiler or script-runner itself
11 such as 'liberating' any dependent .jar files, as described at http://lafros.com/maven/plugins/proguard

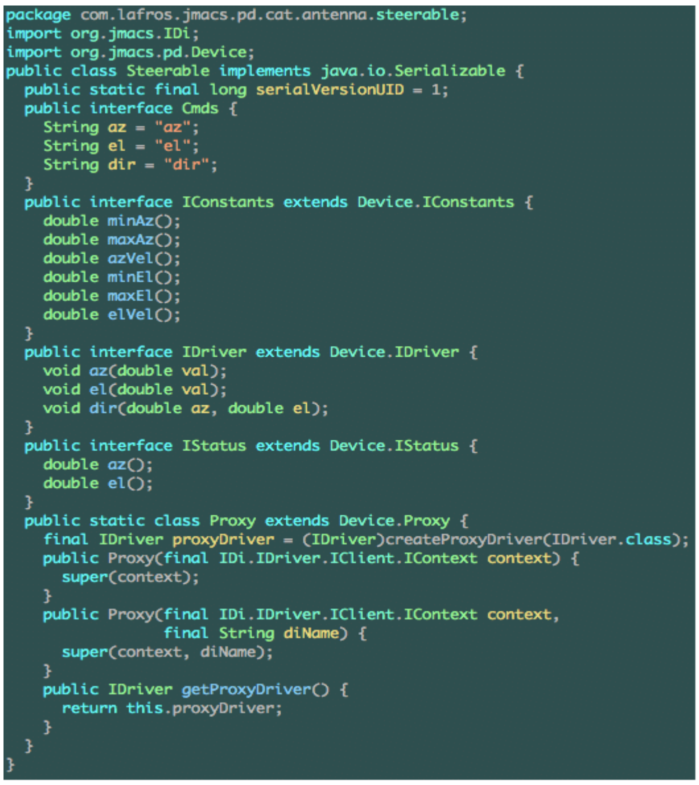
3.2 Use of Scala idioms

As previously mentioned, it was the part of the JMaCS API to do with defining PDs, namely the org.jmacs.pd package, that was most in need of benefiting from being rewritten in Scala, and this indeed turned out to be where most opportunities to employ Scala idioms arose.

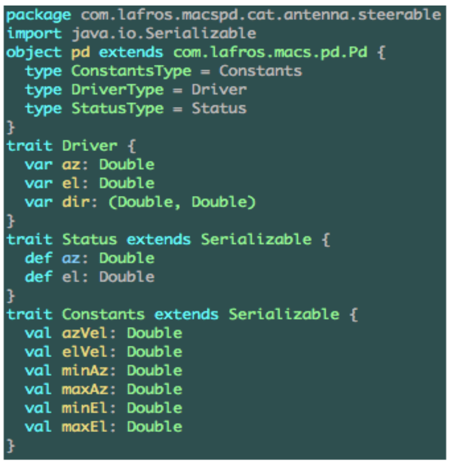
The design pattern found to be of greatest value here is one which will be called the *type-safe singleton*[12], where inner classes referring to abstract type members are exposed via a singleton object. This was employed as follows:

- each element of the PD is represented by either an abstract type member or an inner class/trait of one of six abstract container classes, corresponding to six PD categories (differing according to whether or not status is produced or constants defined);
- each such container class is abstract to the extent of its `DriverType` type member, and also possible `ConstantsType` and `StatusType` ones;
- a PD is defined by defining at least a singleton object--conventionally called `pd`, in a package from which the PD will take its name--which extends the abstract container class for the desired PD category; since this may not be abstract, it will be obliged to assign values to that container class's abstract type members;
- those values should be Scala traits defining the PD's driver, constants and status, and constitute the PD's API;
- any further classes constituting the PD's definition (such as its monitor GUI) may then be defined in a fully type-safe way, by extending the corresponding inner class/trait of the container class, which is now accessible via the singleton object, `pd`.

Note the use of abstract type members rather than type parameters (generics). This was either required in order that the type could be defined in terms of (i.e. bounded by) one of the inner classes/traits, or preferred in order that it could be explicitly specified by an assignment, rather than implicitly, depending on the type parameter's position.



```
package com.lafros.jmacs.pd.cat.antenna.steerable;
import org.jmacs.IDi;
import org.jmacs.pd.Device;
public class Steerable implements java.io.Serializable {
  public static final long serialVersionUID = 1;
  public interface Cmds {
    String az = "az";
    String el = "el";
    String dir = "dir";
  }
  public interface IConstants extends Device.IConstants {
    double minAz();
    double maxAz();
    double azVel();
    double minEl();
    double maxEl();
    double elVel();
  }
  public interface IDriver extends Device.IDriver {
    void az(double val);
    void el(double val);
    void dir(double az, double el);
  }
  public interface IStatus extends Device.IStatus {
    double az();
    double el();
  }
  public static class Proxy extends Device.Proxy {
    final IDriver proxyDriver = (IDriver)createProxyDriver(IDriver.class);
    public Proxy(final IDi.IDriver.IClient.IContext context) {
      super(context);
    }
    public Proxy(final IDi.IDriver.IClient.IContext context,
                 final String diName) {
      super(context, diName);
    }
    public IDriver getProxyDriver() {
      return this.proxyDriver;
    }
  }
}
```



```
package com.lafros.macspd.cat.antenna.steerable
import java.io.Serializable
object pd extends com.lafros.macs.pd.Pd {
  type ConstantsType = Constants
  type DriverType = Driver
  type StatusType = Status
}
trait Driver {
  var az: Double
  var el: Double
  var dir: (Double, Double)
}
trait Status extends Serializable {
  def az: Double
  def el: Double
}
trait Constants extends Serializable {
  val azVel: Double
  val elVel: Double
  val minAz: Double
  val maxAz: Double
  val minEl: Double
  val maxEl: Double
}
```

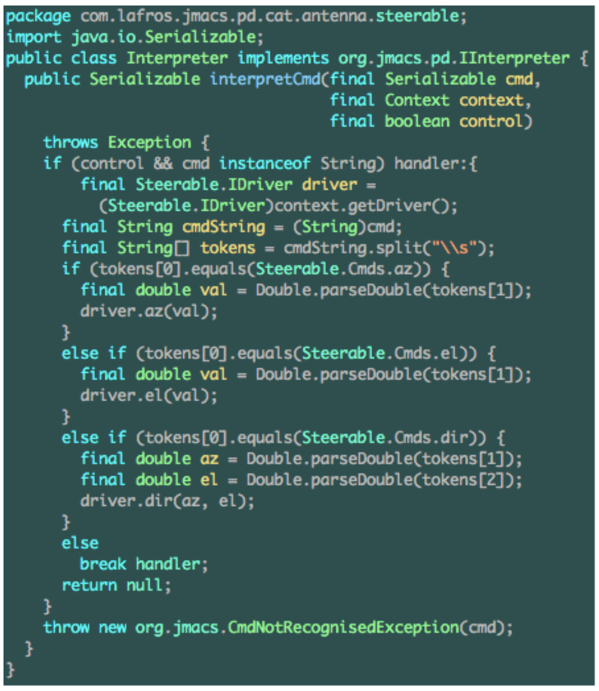
Fig. 1: Steerable antenna API – JMaCS (left) vs MaCS

12 See the subject/observer case study in [5], where the pattern first appears, but without being given a name.

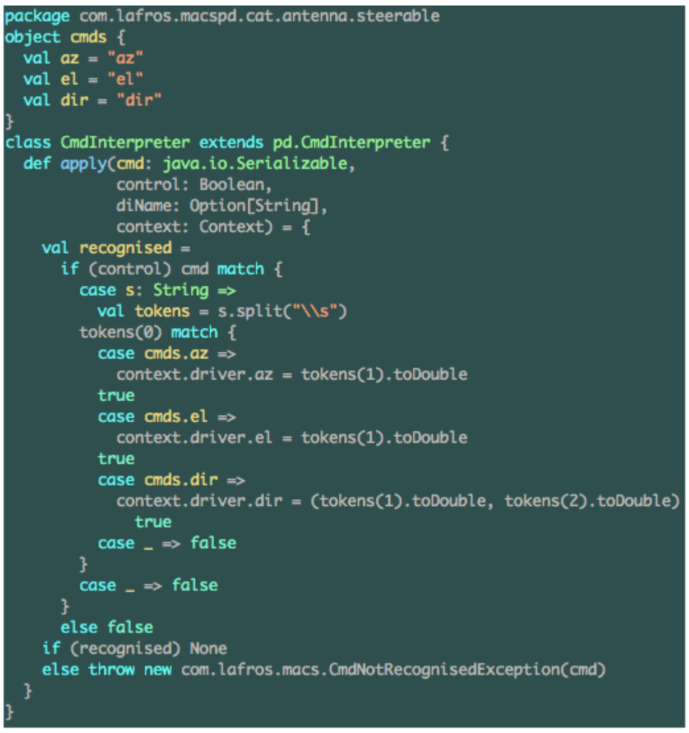
4. RESULTS

4.1 PD definition

We now present a PD definition for a steerable antenna (such as the one at the ESR), having only a very minimal API. Fig. 1 shows the Java code necessary to define the PD's API in the case of JMaCS, next to the Scala code necessary in the case of MaCS. As can be seen, the weaknesses pointed out earlier have been eliminated in the MaCS case.



```java
package com.lafros.jmacs.pd.cat.antenna.steerable;
import java.io.Serializable;
public class Interpreter implements org.jmacs.pd.IInterpreter {
  public Serializable interpretCmd(final Serializable cmd,
                                   final Context context,
                                   final boolean control)
    throws Exception {
    if (control && cmd instanceof String) handler:{
        final Steerable.IDriver driver =
          (Steerable.IDriver)context.getDriver();
      final String cmdString = (String)cmd;
      final String[] tokens = cmdString.split("\\s");
      if (tokens[0].equals(Steerable.Cmds.az)) {
        final double val = Double.parseDouble(tokens[1]);
        driver.az(val);
      }
      else if (tokens[0].equals(Steerable.Cmds.el)) {
        final double val = Double.parseDouble(tokens[1]);
        driver.el(val);
      }
      else if (tokens[0].equals(Steerable.Cmds.dir)) {
        final double az = Double.parseDouble(tokens[1]);
        final double el = Double.parseDouble(tokens[2]);
        driver.dir(az, el);
      }
      else
        break handler;
      return null;
    }
    throw new org.jmacs.CmdNotRecognisedException(cmd);
  }
}
```



```scala
package com.lafros.macspd.cat.antenna.steerable
object cmds {
  val az = "az"
  val el = "el"
  val dir = "dir"
}
class CmdInterpreter extends pd.CmdInterpreter {
  def apply(cmd: java.io.Serializable,
            control: Boolean,
            diName: Option[String],
            context: Context) = {
    val recognised =
      if (control) cmd match {
        case s: String =>
          val tokens = s.split("\\s")
        tokens(0) match {
          case cmds.az =>
            context.driver.az = tokens(1).toDouble
          true
          case cmds.el =>
            context.driver.el = tokens(1).toDouble
          true
          case cmds.dir =>
            context.driver.dir = (tokens(1).toDouble, tokens(2).toDouble)
            true
          case _ => false
        }
        case _ => false
      }
      else false
    if (recognised) None
    else throw new com.lafros.macs.CmdNotRecognisedException(cmd)
  }
}
```

Fig. 2: Command interpreter - JMaCS (left) vs MaCS

Fig. 2 shows, side by side as before, the two versions of the command interpreter. The main difference to note here is that, by extending `pd.CmdInterpreter`, only the MaCS version is fully type-safe, whereas the JMaCS one is required to cast the driver (from the tag type to the type defined by the PD). Note also that the commands are defined in the same file in the MaCS case, which is not possible in the JMaCS one. This example also illustrates how Scala's pattern-matching can provide a cleaner alternative to conditionals.

It may be similarly shown how, by extending `pd.MonitorGui`, only the MaCS version of the monitor GUI is fully type-safe. Note that full type-safety with respect to the PD's API is not an issue in the case of the control-panel GUI, since this may not reference the driver directly, but only the commands[13].

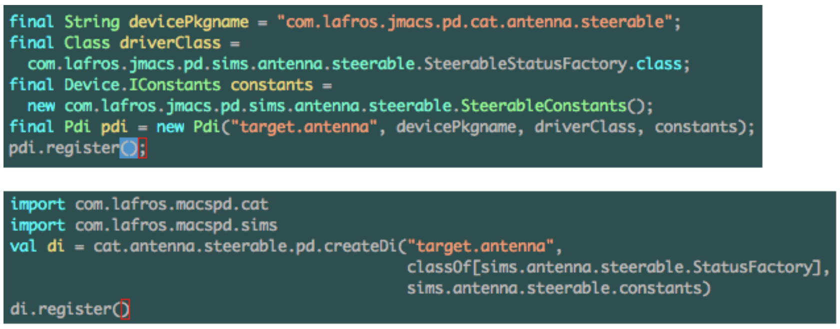
4.2 PD implementation

In the present case, it is appropriate not to include an implementation of the PD's API as part of the PD definition, so as not to limit its reusability. To provide one in this case requires a status factory, which once again, by extending `pd.StatusFactory`, may only be written in a fully type-safe way in the MaCS case.

4.3 PD deployment

Fig. 3 shows JMaCS and MaCS versions of the code required to create a DI-client object, given a concrete implementation of our example PD. Here again, only the MaCS version (bottom) is fully type-safe.

13 However, MaCS still provides the class, `pd.ControlsGui`, in order that the subclass may itself be called 'ControlsGui', as is required.



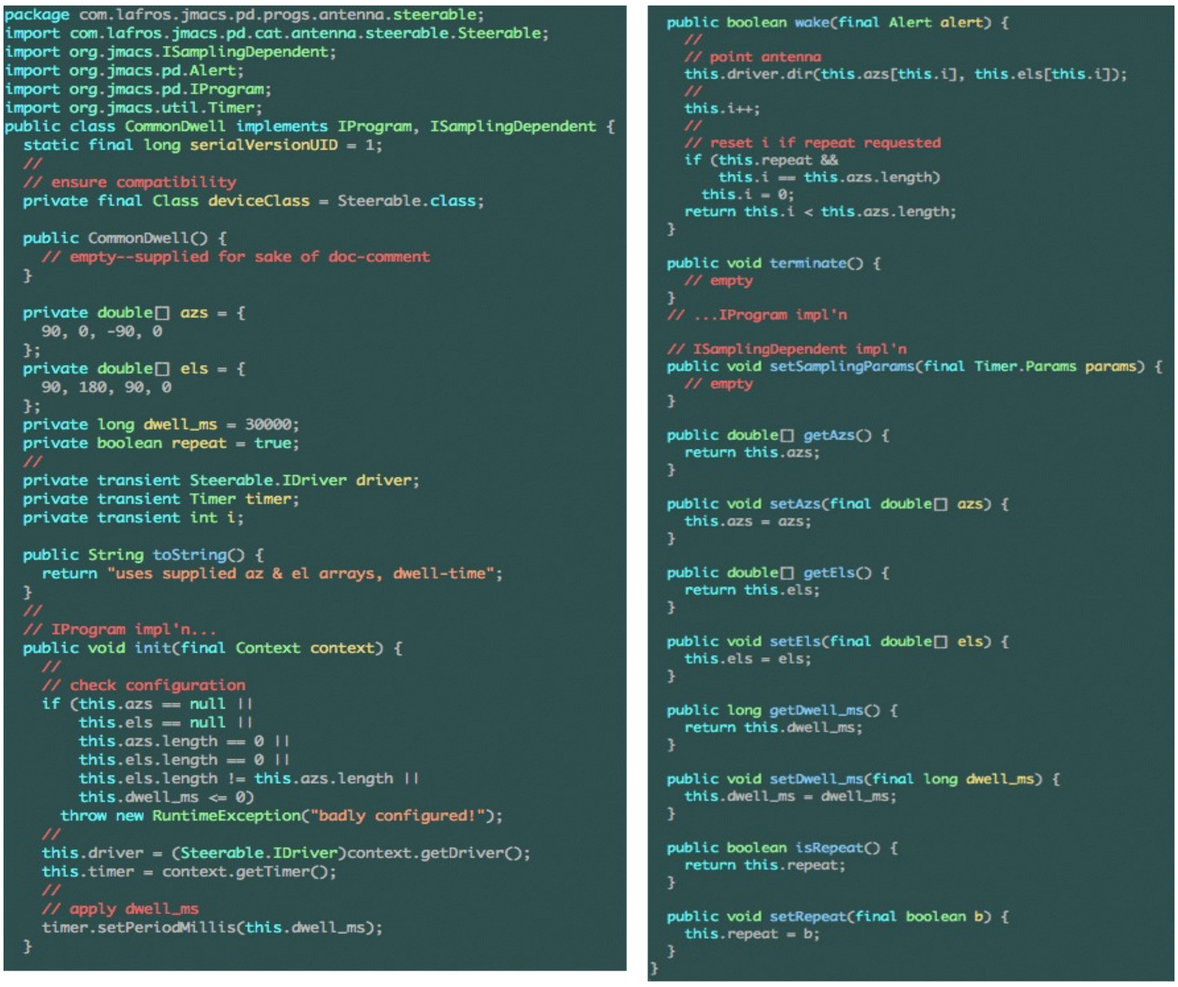
```java
final String devicePkgname = "com.lafros.jmacs.pd.cat.antenna.steerable";
final Class driverClass =
  com.lafros.jmacs.pd.sims.antenna.steerable.SteerableStatusFactory.class;
final Device.IConstants constants =
  new com.lafros.jmacs.pd.sims.antenna.steerable.SteerableConstants();
final Pdi pdi = new Pdi("target.antenna", devicePkgname, driverClass, constants);
pdi.register();
```

```scala
import com.lafros.macspd.cat
import com.lafros.macspd.sims
val di = cat.antenna.steerable.pd.createDi("target.antenna",
                                           classOf[sims.antenna.steerable.StatusFactory],
                                           sims.antenna.steerable.constants)
di.register()
```

Fig. 3: Deployment code - JMaCS (top) vs MaCS

4.4 PD programs

Fig. 4 shows the JMaCS version of an example program for our example PD, having properties that may be configured so as to point the antenna in a sequence of directions.

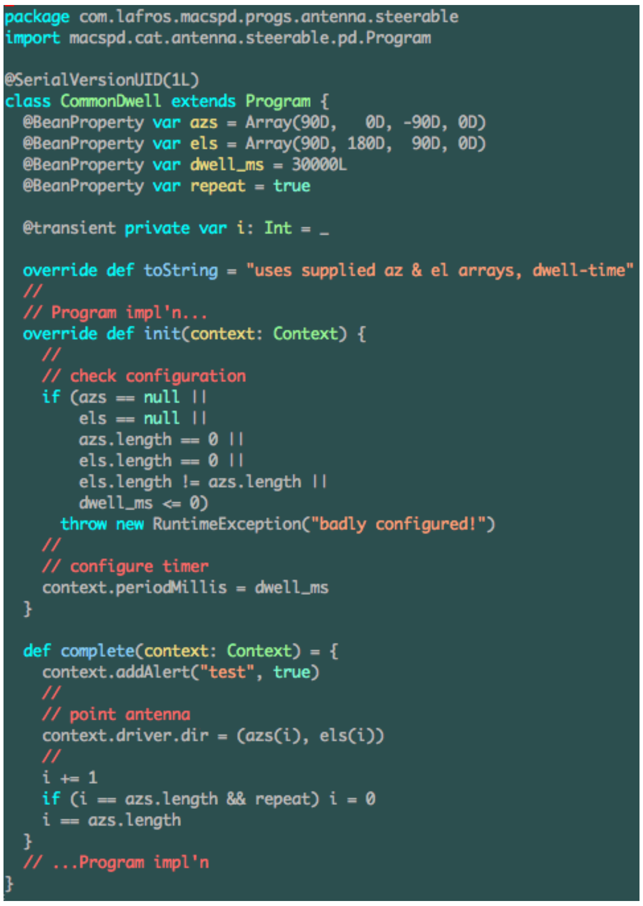


```java
package com.lafros.jmacs.pd.progs.antenna.steerable;
import com.lafros.jmacs.pd.cat.antenna.steerable.Steerable;
import org.jmacs.ISamplingDependent;
import org.jmacs.pd.Alert;
import org.jmacs.pd.IProgram;
import org.jmacs.util.Timer;
public class CommonDwell implements IProgram, ISamplingDependent {
  static final long serialVersionUID = 1;
  //
  // ensure compatibility
  private final Class deviceClass = Steerable.class;

  public CommonDwell() {
    // empty--supplied for sake of doc-comment
  }

  private double[] azs = {
    90, 0, -90, 0
  };
  private double[] els = {
    90, 180, 90, 0
  };
  private long dwell_ms = 30000;
  private boolean repeat = true;
  //
  private transient Steerable.IDriver driver;
  private transient Timer timer;
  private transient int i;

  public String toString() {
    return "uses supplied az & el arrays, dwell-time";
  }
  //
  // IProgram impl'n...
  public void init(final Context context) {
    //
    // check configuration
    if (this.azs == null ||
        this.els == null ||
        this.azs.length == 0 ||
        this.els.length == 0 ||
        this.els.length != this.azs.length ||
        this.dwell_ms <= 0)
      throw new RuntimeException("badly configured!");
    //
    this.driver = (Steerable.IDriver)context.getDriver();
    this.timer = context.getTimer();
    //
    // apply dwell_ms
    timer.setPeriodMillis(this.dwell_ms);
  }
```

```java
  public boolean wake(final Alert alert) {
    //
    // point antenna
    this.driver.dir(this.azs[this.i], this.els[this.i]);
    //
    this.i++;
    //
    // reset i if repeat requested
    if (this.repeat &&
        this.i == this.azs.length)
      this.i = 0;
    return this.i < this.azs.length;
  }

  public void terminate() {
    // empty
  }
  // ...IProgram impl'n

  // ISamplingDependent impl'n
  public void setSamplingParams(final Timer.Params params) {
    // empty
  }

  public double[] getAzs() {
    return this.azs;
  }

  public void setAzs(final double[] azs) {
    this.azs = azs;
  }

  public double[] getEls() {
    return this.els;
  }

  public void setEls(final double[] els) {
    this.els = els;
  }

  public long getDwell_ms() {
    return this.dwell_ms;
  }

  public void setDwell_ms(final long dwell_ms) {
    this.dwell_ms = dwell_ms;
  }

  public boolean isRepeat() {
    return this.repeat;
  }

  public void setRepeat(final boolean b) {
    this.repeat = b;
  }
}
```

Fig. 4: Example program - JMaCS version

Fig. 5 shows the MaCS version of the same program.



```
package com.lafros.macspd.progs.antenna.steerable
import macspd.cat.antenna.steerable.pd.Program

@SerialVersionUID(1L)
class CommonDwell extends Program {
  @BeanProperty var azs = Array(90D,   0D, -90D, 0D)
  @BeanProperty var els = Array(90D, 180D,  90D, 0D)
  @BeanProperty var dwell_ms = 30000L
  @BeanProperty var repeat = true

  @transient private var i: Int = _

  override def toString = "uses supplied az & el arrays, dwell-time"
  //
  // Program impl'n...
  override def init(context: Context) {
    //
    // check configuration
    if (azs == null ||
        els == null ||
        azs.length == 0 ||
        els.length == 0 ||
        els.length != azs.length ||
        dwell_ms <= 0)
      throw new RuntimeException("badly configured!")
    //
    // configure timer
    context.periodMillis = dwell_ms
  }

  def complete(context: Context) = {
    context.addAlert("test", true)
    //
    // point antenna
    context.driver.dir = (azs(i), els(i))
    //
    i += 1
    if (i == azs.length && repeat) i = 0
    i == azs.length
  }
  // ...Program impl'n
}
```

Fig. 5: Example program - MaCS version

Once again, only the latter is fully type-safe, while also being somewhat more concise.

The following should also be noted, with regard to the MaCS version:

- the `@BeanProperty` annotation tells the compiler to add corresponding Java-style accessor methods, to allow property configuration using existing Java tools;
- there is no `terminate()`, since an empty implementation is already supplied by the `Program` trait—the corresponding `IProgram` Java interface in the JMaCS case is not allowed to do this;
- a non-language-related refinement of the API now means that the program need no longer extend an equivalent of `ISamplingDependent` in order to prevent its associated timer being reconfigured whenever the parameters controlling status sampling are changed.

5. CONCLUSIONS

The Lafros MaCS software, written in Scala, has been presented, and compared with it predecessor, JMaCS, written in Java.

It has been shown that PD API definitions are cleaner and more concise, when written to the MaCS API, in Scala, than when written to the JMaCS one, in Java.

Furthermore, it has also been shown that the remainder of each PD definition, together with PD implementations, PD deployment code, and PD programs, may be written in a way that is fully type-safe with respect to the PD's API, in the MaCS/Scala case, that was not possible in the JMaCS/Java one.

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