The Timing Definition Language (TDL)

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Overview

- TDL programming model for concurrent hard real-time software
- TDL component model
- Simple TDL example
- Tool chain
- Current state

What is TDL?

- A high-level textual notation for defining the timing behavior of a real-time application.
- Conceptually based on Giotto (University of California, Berkeley).
- **TDL = Giotto + syntax + component architecture + cleanups.**

Analogy: IDL (CORBA, MIDL) vs. TDL

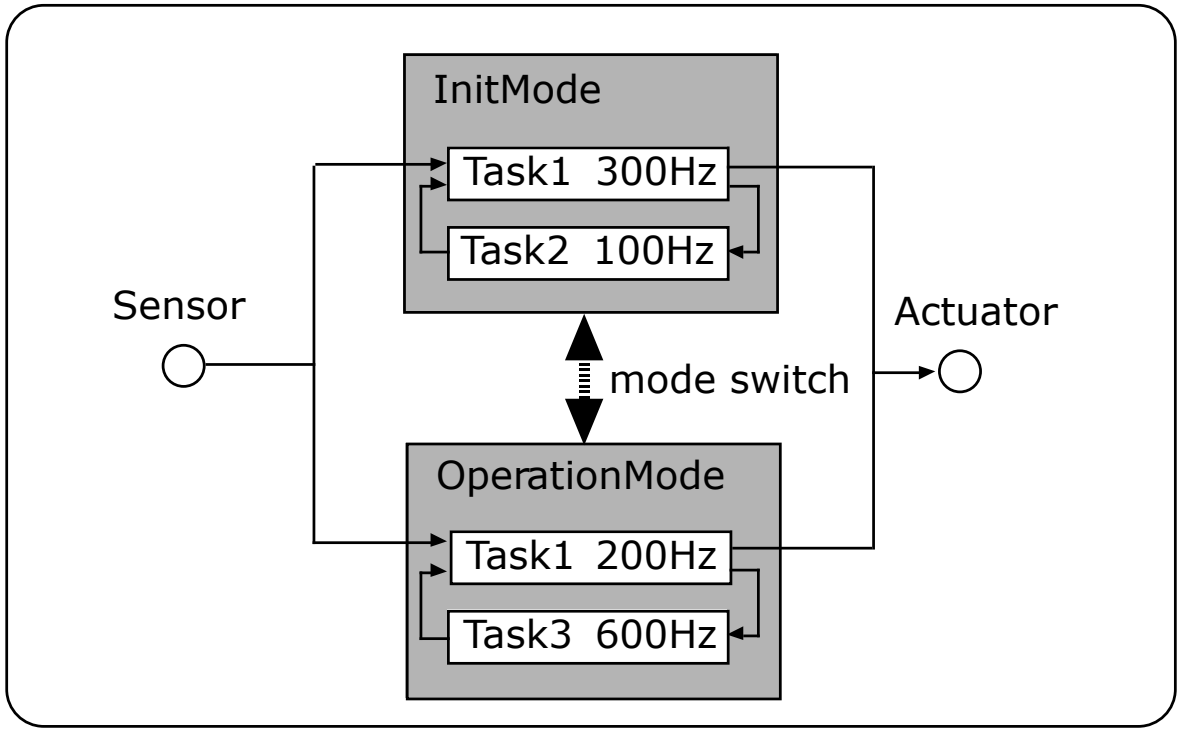
IDL defines an interface for a distributed application

=> Separates interface from implementation

TDL defines the timing for a real-time application

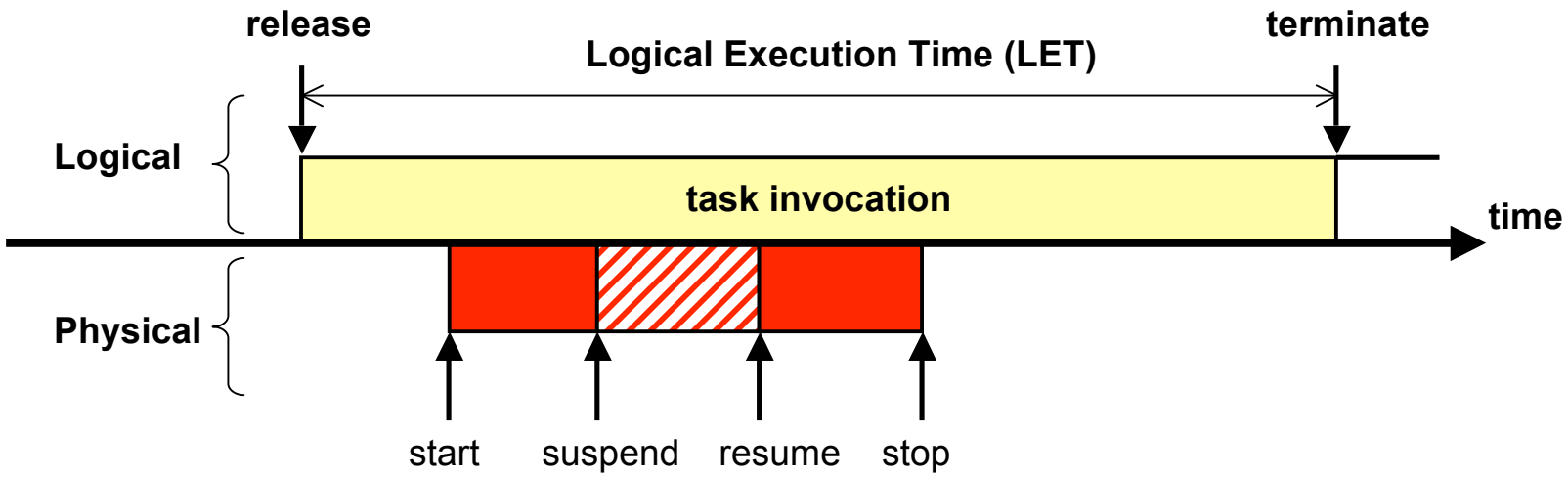
=> Separates timing from implementation

Schematic overview of Giotto/TDL concepts



Giotto programs are multi mode & multi rate systems for long running tasks.

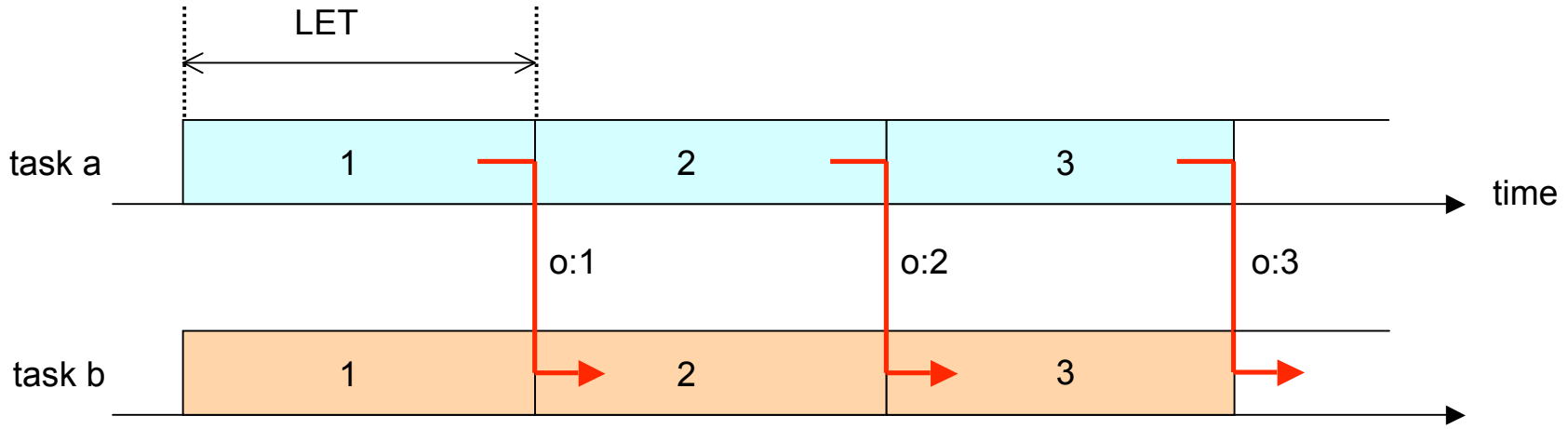
The Giotto/TDL Programming Model (LET)



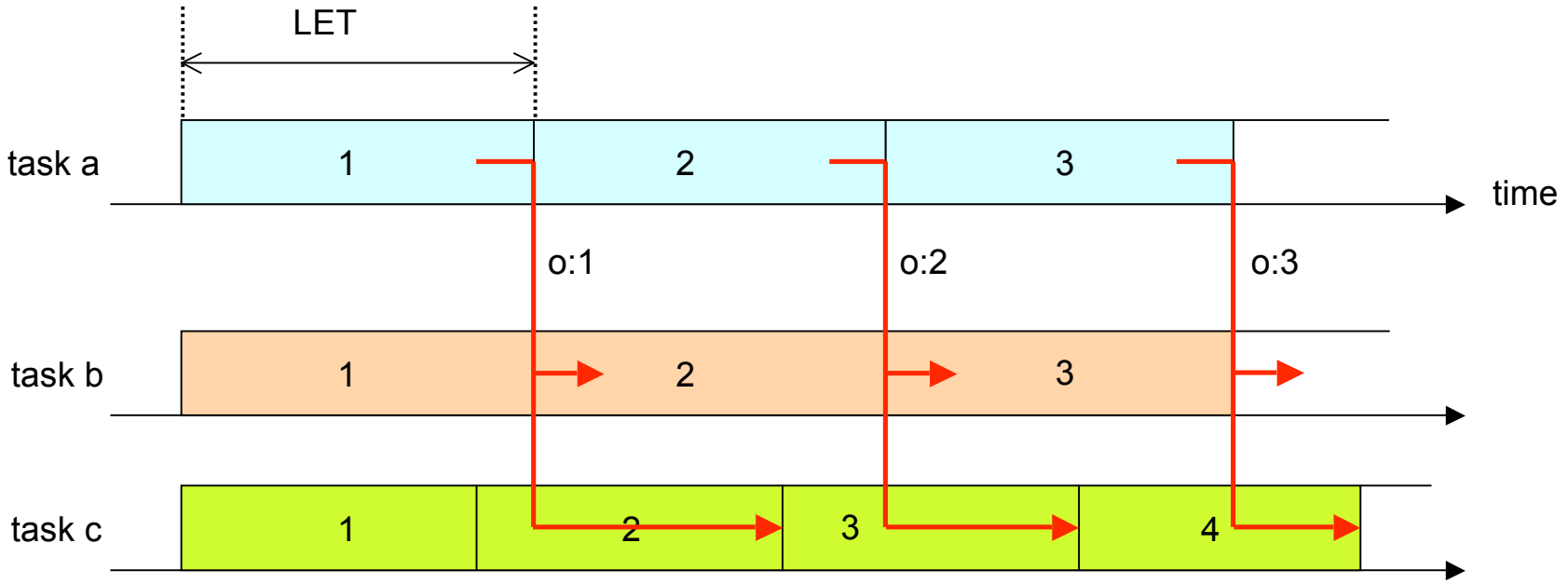
ET <= WCET <= LET

results are available at 'terminate'

Unit Delay



Unit Delay



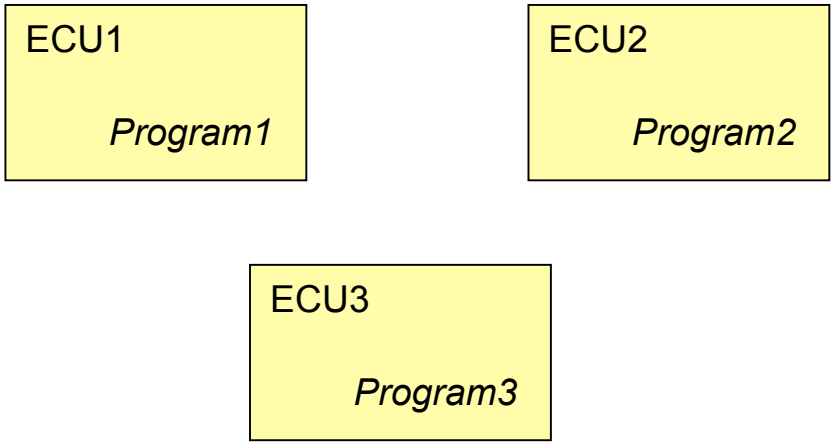
... but isn't it a waste of time?

=> determinism, composition, transparent distribution

Summary of Giotto Heritage

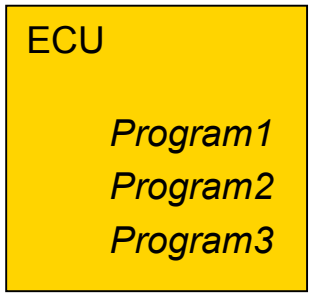
- Sensor and actuator ports are used to interact with the environment.
- A program is in one of potentially multiple modes.
- Every mode consists of periodic activities:
  - task invocations
  - actuator updates
  - mode switches
- A mode has a fixed period.
- Activities are carried out conditionally.
- Activities have their individual execution rate.
- Timing and interaction of activities follows LET semantics.

TDL Component Model: Motivation



- e.g. modern cars have up to 80 control units (ECUs)
- ECU consolidation is a topic
- run multiple programs on one ECU
- leads to TDL component model

TDL Component Model



- ProgramX is called a *module*
- modules may be independent
- modules may also refer to each other (DAG)
- modules can be used for multiple purposes

Usage of Modules

- decomposition of large programs
- grouping of unrelated modules
- parallel automatons
- ECU consolidation
- client/service relationship
  - provide common definitions for constants, types, etc.
  - data flow from service to client module
- distributed execution

TDL Syntax by Example

```
module M1 {

  sensor boolean s1 uses getS1;
  actuator int a1 uses setA1;

  public task inc [wcet=4ms] {
    output int o := 10;
    uses incImpl(o);
  }

  start mode main [period=10ms] {
    task
      [freq=1] inc();
    actuator
      [freq=2] a1 := inc.o;
    mode
      [freq=1] if exitMain(s1) then freeze;
  }

  mode freeze [period=1000ms] {}
}
```

Module Import

```
module M2{

  import M1;
  …
  task clientTask [wcet=10ms] {
    input int i1;
    …
  }
  mode main [period=100ms] {
    task [freq=1] clientTask(M1.inc.o);
    …
  }
}
```

- Import relationship forms a DAG.
- TDL supports structured module names (e.g. `com.avl.p1.M1`)
- import with rename: (e.g. `import com.avl.p1.M1 as A1;`)
- group import: (e.g. `import com.avl.p1 {M1, M2, M3};`)

Module Summary

- provides a named program component
- provides a name space
- allows for exporting sensors, constants, types, task outputs
- may be imported by other module(s)
- acts as unit of composition
- acts as the unit of loading
- acts as the unit of execution
- partitions the set of actuators
- acts as the unit of distribution

TDL supports multi mode & multi rate & multi program systems.

More Language Constructs

- Constants

```
const c1 = 100;
const p = 100ms;
```

- Types

  Basic types: like Java

  `byte`, `short`, `int`, ...

  User defined opaque types: defined externally

```
type T;
```

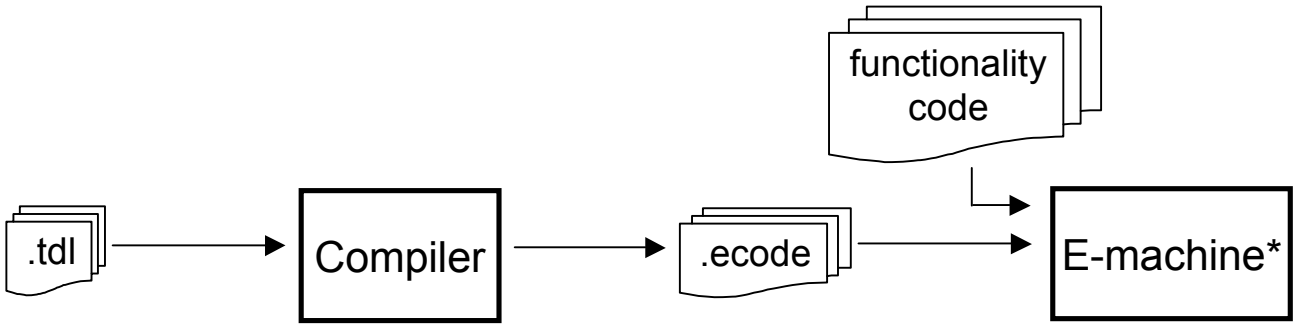
Differences to Giotto

- TDL provides a component model (module).
- TDL defines a concrete syntax and .ecode file format.
- TDL does not need explicit task invocation drivers, mode switch drivers and actuator update drivers as Giotto does.

  Drivers are defined implicitly by the TDL syntax and semantics.

  The user needs to implement only guards, sensor getters, actuator setters, port initializers, and, of course, task functions.
- TDL defines program start as mode switch to start mode.
- TDL disallows non-harmonic mode switches.
- Mode port assignments differ.
- Timing is in us.

Tool Chain Overview



*Java, OSEK, InTIME, RTLinux, ...

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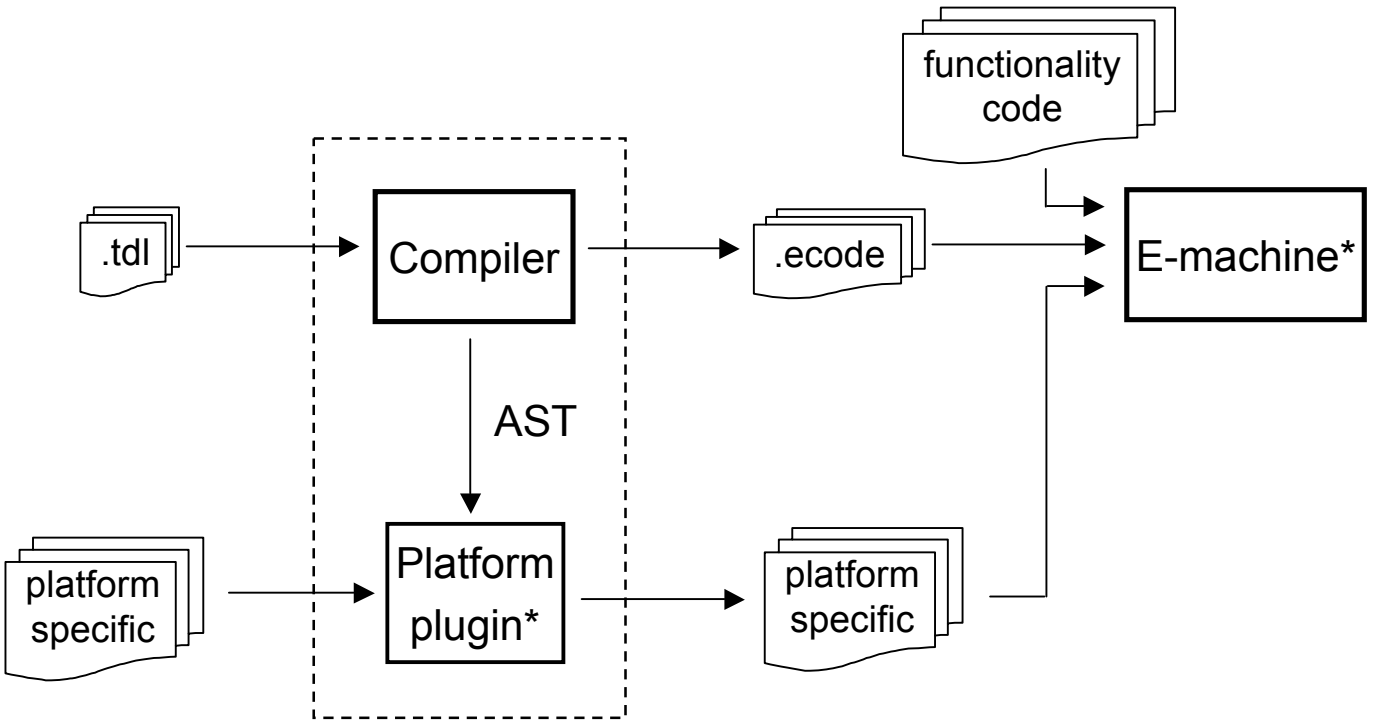

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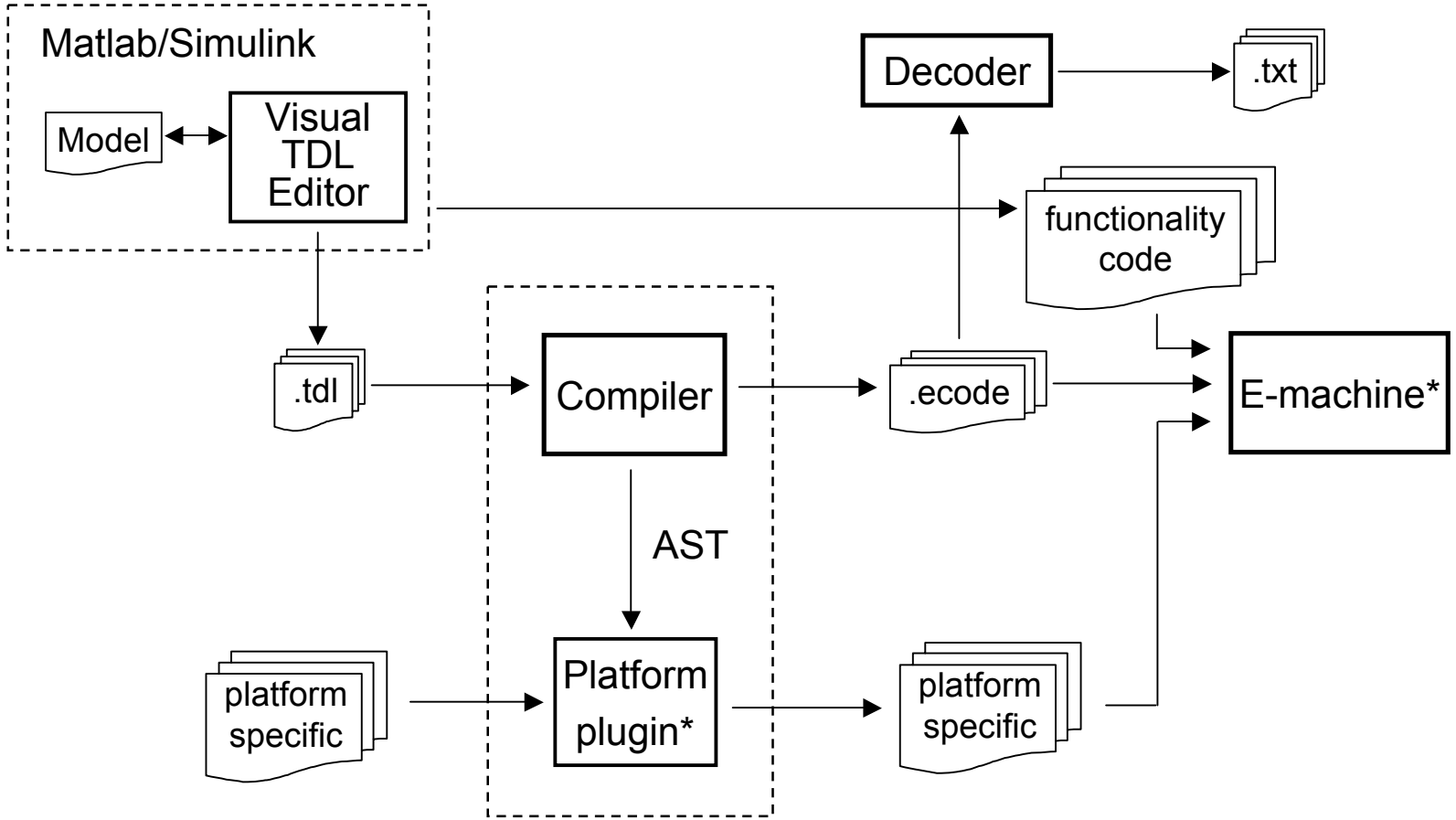

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Source Code Organization

`emcore`	(37.775 loc)
`ast`	abstract syntax tree (1.180)
`ecode`	ecode instructions and reader (613)
`scheduler`	node schedulers (1.039)
`tools`	(34.829)
`decode`	`.`ecode decoder (222)
`emachine`	E-machine (3.323)
`tdlc`	TDL compiler (5.248)
`platform`	standard platform plugins (2.261)
`vtdl`	visual TDL editor (24.198)
`busch`	bus scheduler (1.824)
`util`	various utility classes (114)

TDL Compiler

- implemented with compiler generator Coco/R for Java.
  (Mössenböck, JKU Linz)
  production quality recursive descent compiler in Java.
  2 phases:
    1. parse source text and build AST
    2. generate .ecode file from AST

- plugin interface defined by base class *Platform*
- plugin life cycle: `open {emitCode} close`
- additionally: `setErrorHandler, setDestDir`

Java-based E-machine

- used as proof of concept
- experimentation platform
- not hard-real time
- consists of
  - .ecode loader
  - task scheduler
  - E-code interpreter
  - dispatcher
  - bus controller (for distribution)
- Interacts with functionality code via drivers

State

- Ready
  - TDL Compiler for complete TDL
  - Decoder
  - Java-based E-machine for multiple modules
  - Visual TDL Editor
  - InTIME, OSEK, TTA
  - TDK (from MoDECS.cc)
- Work in Progress
  - ANSI C back ends for POSIX, RTLinux, OSEK, InTIME…
  - E-machines for distribution
  - Bus Scheduler

Thank you for your attention!

TDK - TDL Development Kit

- preconfigured collection of Java-based TDL tools (tdlc, emachine, decoder, Java plugin, JavaDocs, Tutorial)
- for learning TDL and for easy experimentation with real time applications
- batch files for Windows command prompt
- downloadable from MoDECS home page (MoDECS.cc)
- TDL Tutorial:
  - Explains how to use the TDL tools from command line.
  - Uses sequence of examples with increasing complexity:

    single rate, multi rate, multi mode, multi module, [multi node]