Transitioning from Crescendo to INTO-CPS

Kenneth Lausdahl\textsuperscript{1}  Kim Bjerge\textsuperscript{1}  Tom Bokhove\textsuperscript{2}  
Frank Groen\textsuperscript{2}  Peter Gorm Larsen\textsuperscript{1}

Aarhus University, Denmark

Controllab Products, Netherlands

15th Overture workshop
Newcastle, UK – September 15
Agenda

Technologies

Tool Extensions

Case-Study

Animation

Conclusion and future plans
Agenda

Technologies

Tool Extensions

Case-Study

Animation

Conclusion and future plans
DESTECS - Crescendo
INTO-CPS

- FMI 2.0 based co-simulation
- Simulation of N models
- Multi platform
- Uses SysML for high level design
- Both Fixed and Variable Step algorithms
INTO-CPS

FMI

Functional Mock-Up Interface

- A collection of C functions
  - instantiate
  - setInteger|Boolean|Real|String
  - doStep
  - getInteger|Boolean|Real|String

- Zip container with standard layout for: Linux, Mac and Windows
  - binaries/
  - resources/
  - modelDescription.xml
INTO-CPS

Variable Simulation Algorithm

- Zero Crossing
  - Reduce step size near zero crossing
- Bounded Difference
- Sampling Rate
- FMU Max Step Size
INTO-CPS

Variable Simulation Algorithm

- Zero Crossing
  - Reduce step size near zero crossing
- Bounded Difference
- Sampling Rate
- FMU Max Step Size

```plaintext
class A

thread periodic (20E6, 0, 0, 20E6) (step); // 0.02 seconds

operations
step : () ==> ()
step() == duration(0) skip;

end A
```
INTO-CPS

Variable Simulation Algorithm

- Zero Crossing
  - Reduce step size near zero crossing
- Bounded Difference
- Sampling Rate
- FMU Max Step Size

```plaintext
class A

thread
periodic (20E6, 0, 0, 20E6) (step); //0.02 seconds

operations
step : () ==> ()
step() == duration(0) skip;
end A
```
INTO-CPS

Variable Simulation Algorithm

- Zero Crossing
  - Reduce step size near zero crossing
- Bounded Difference
- Sampling Rate
- FMU Max Step Size

```plaintext
class A

thread
periodic (20E6, 0, 0, 20E6) (step); //0.02 seconds

operations
step : () ==> ()
step() == duration(0) skip;

end A
```
INTO-CPS

Simulation Algorithm: Zero Crossing Example

Constraint: zero crossing
Ports: (level, max)

Constraint: zero crossing
Ports: (level, min)
Agenda

Technologies

Tool Extensions

Case-Study

Animation

Conclusion and future plans
Overture FMI

- Added new FMI library
  - BoolPort
  - IntPort
  - RealPort
  - StringPort
Overture FMI

- Added new FMI library
  - BoolPort
  - IntPort
  - RealPort
  - StringPort

```java
class HardwareInterface
values
  -- @ interface: type = parameter;
  public v : RealPort = new RealPort(1.0);

instance variables
  -- @ interface: type = input;
  public distanceTravelled : RealPort := new RealPort(0.0);
  -- @ interface: type = output;
  public setAngle : RealPort := new RealPort(0.0);
end HardwareInterface
```
Overture FMI

- Added new FMI library
  - BoolPort
  - IntPort
  - RealPort
  - StringPort

```java
system System
instance variables
  -- Hardware interface variable required by FMU Import/Export
public static hwi:HardwareInterface:=new HardwareInterface();
...
operations
public System : () ==> System
System () ==
(
  ctrl := new Controller(hwi);
  cpu1.deploy(ctrl, "Controller");
);
end System
```
20-sim

- Generate an FMU for a model
- Direct calls from the FMU into 20-sim
Agenda

Technologies

Tool Extensions

Case-Study

Animation

Conclusion and future plans
Case-Study
Case-Study

DESTECS Contract

```
sdp real v;
sdp real r2;
sdp real r4;
sdp real l1;
sdp real l3;
sdp real trayPitch;
sdp real p;

controlled real setAngle := 0.0;

monitored real distanceTravelled := 0.0;
monitored real distCTB1 := 0.0;
monitored real distCTB2 := 0.0;
monitored real distCTB3 := 0.0;
monitored real distCTB4 := 0.0;

event eventCTB1;
event eventCTB2;
event eventCTB3;
event eventCTB4;
```
Case-Study

DESTECS Contract

```plaintext
sdp real v;
sdp real r2;
sdp real r4;
sdp real l1;
sdp real l3;
sdp real trayPitch;
sdp real p;

controlled real setAngle := 0.0;

monitored real distanceTravelled := 0.0;
monitored real distCTB1 := 0.0;
monitored real distCTB2 := 0.0;
monitored real distCTB3 := 0.0;
monitored real distCTB4 := 0.0;

event eventCTB1;
event eventCTB2;
event eventCTB3;
event eventCTB4;
```
Case-Study

DESTECS Contract

```plaintext
sdp real v;
sdp real r2;
sdp real r4;
sdp real l1;
sdp real l3;
sdp real trayPitch;
sdp real p;

controlled real setAngle := 0.0;

monitored real distanceTravelled := 0.0;
monitored real distCTB1 := 0.0;
monitored real distCTB2 := 0.0;
monitored real distCTB3 := 0.0;
monitored real distCTB4 := 0.0;

event eventCTB1;
event eventCTB2;
event eventCTB3;
event eventCTB4;
```
Case-Study

DESTECS Contract

\[
\begin{align*}
\text{sdp real } & \quad v; \\
\text{sdp real } & \quad r_2; \\
\text{sdp real } & \quad r_4; \\
\text{sdp real } & \quad l_1; \\
\text{sdp real } & \quad l_3; \\
\text{sdp real } & \quad \text{trayPitch}; \\
\text{sdp real } & \quad p;
\end{align*}
\]

controlled real setAngle := 0.0;

monitored real distanceTravelled := 0.0;
monitored real distCTB1 := 0.0;
monitored real distCTB2 := 0.0;
monitored real distCTB3 := 0.0;
monitored real distCTB4 := 0.0;

event eventCTB1;
event eventCTB2;
event eventCTB3;
event eventCTB4;
Case-Study

DESTEC Contract

```plaintext
sdp real v;
sdp real r2;
sdp real r4;
sdp real l1;
sdp real l3;
sdp real trayPitch;
sdp real p;

controlled real setAngle := 0.0;

monitored real distanceTravelled := 0.0;
monitored real distCTB1 := 0.0;
monitored real distCTB2 := 0.0;
monitored real distCTB3 := 0.0;
monitored real distCTB4 := 0.0;

event eventCTB1;
event eventCTB2;
event eventCTB3;
event eventCTB4;
```
Case-Study

DESTECs Simulation - result

Crescendo bankAngle

Crescendo desiredBankAngle
Case-Study

INTO-CPS
Case-Study

INTO-CPS Simulation - result
Case-Study
INTO-CPS Simulation - result
Case-Study

INTO-CPS Simulation - result
Agenda

Technologies

Tool Extensions

Case-Study

Animation

Conclusion and future plans
Animation

20sim 3D Animation
Animation

Automated conversion to Unity
Animation

Unity FMI Support

Export Tool Wrapper FMU
Generate:
- unity excitable (.exe)
- modelDescription.xml

Unity Plug-in

Unity Executable

FMU

Co-Simulation
Agenda

Technologies

Tool Extensions

Case-Study

Animation

Conclusion and future plans
Conclusion and future plans

- Successful transition of the trolley conveyor case study
- Events can be supported through constraints
- Automatic translation from 20sim 3D to Unity
- Enabled FMI for Unity
Thank you

INTO-CPS