Transitioning from Crescendo to INTO-CPS

Kenneth Lausdahl[1] Kim Bjerge[1] Tom Bokhove[2]
Frank Groen[2] Peter Gorm Larsen[1]

Aarhus University, Denmark

Controllab Products, Netherlands

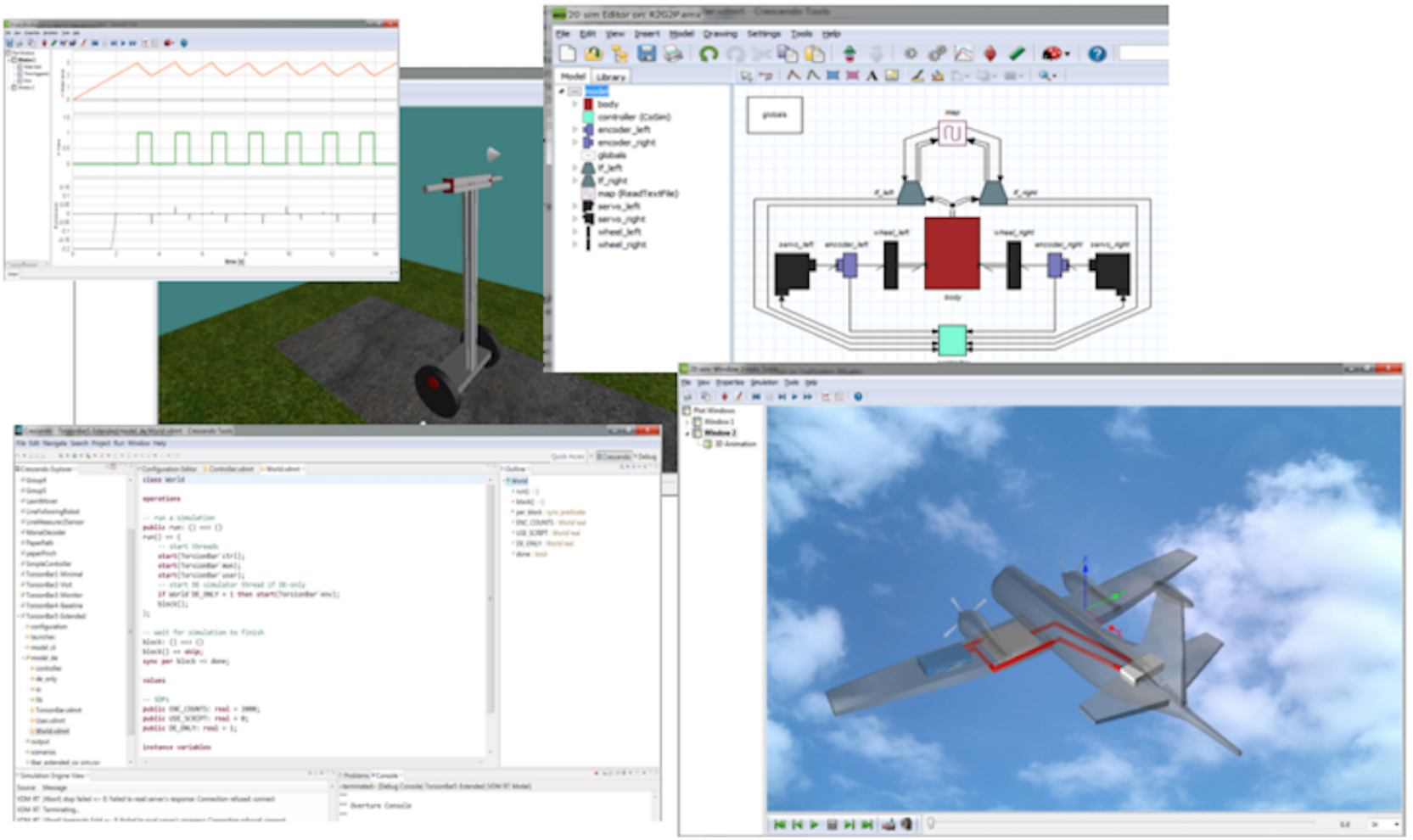
15th Overture workshop
Newcastle, UK – September 15

Agenda

- Technologies
- Tool Extensions
- Case-Study
- Animation
- Conclusion and future plans

Agenda

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|Boolen|Real|String`
  - `doStep`
  - `getInteger|Boolen|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

```
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

```
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

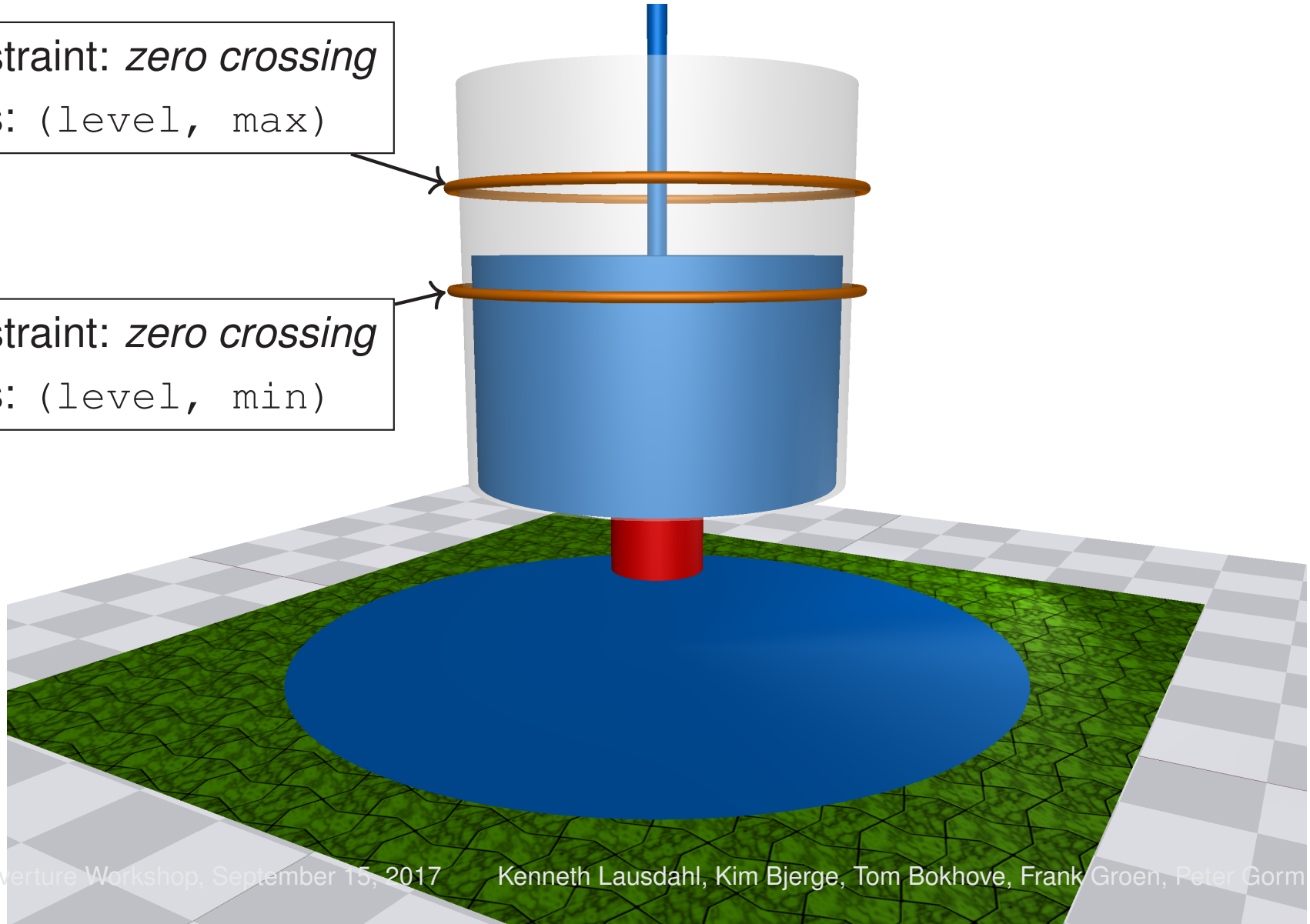
```
class A

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`

```
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
```

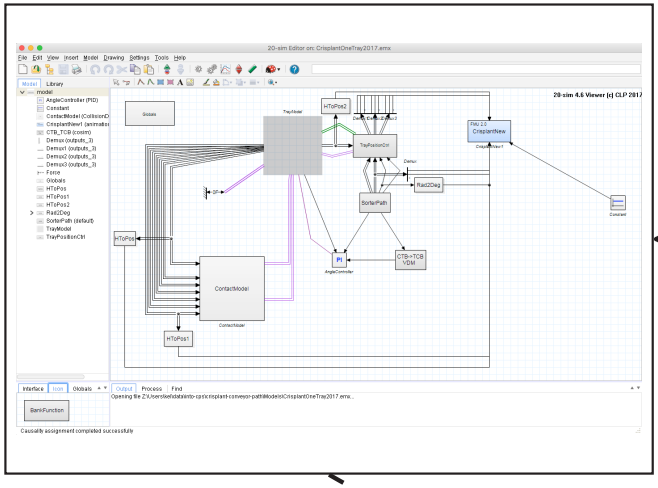
Overture FMI

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

```
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



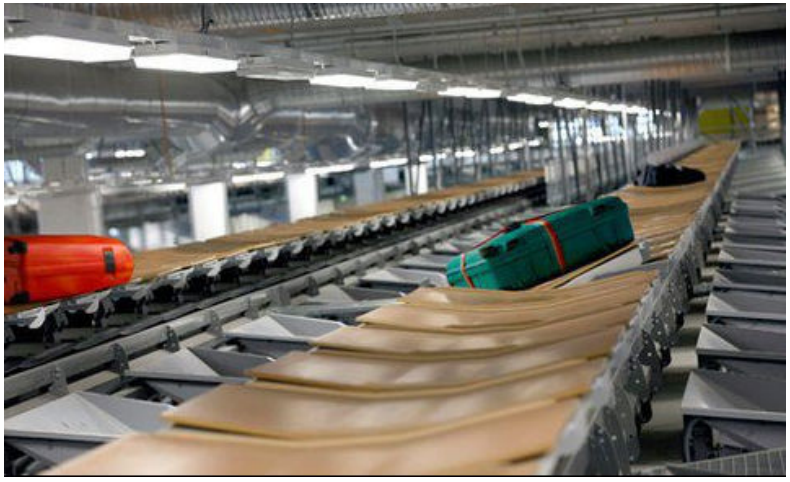
FMU

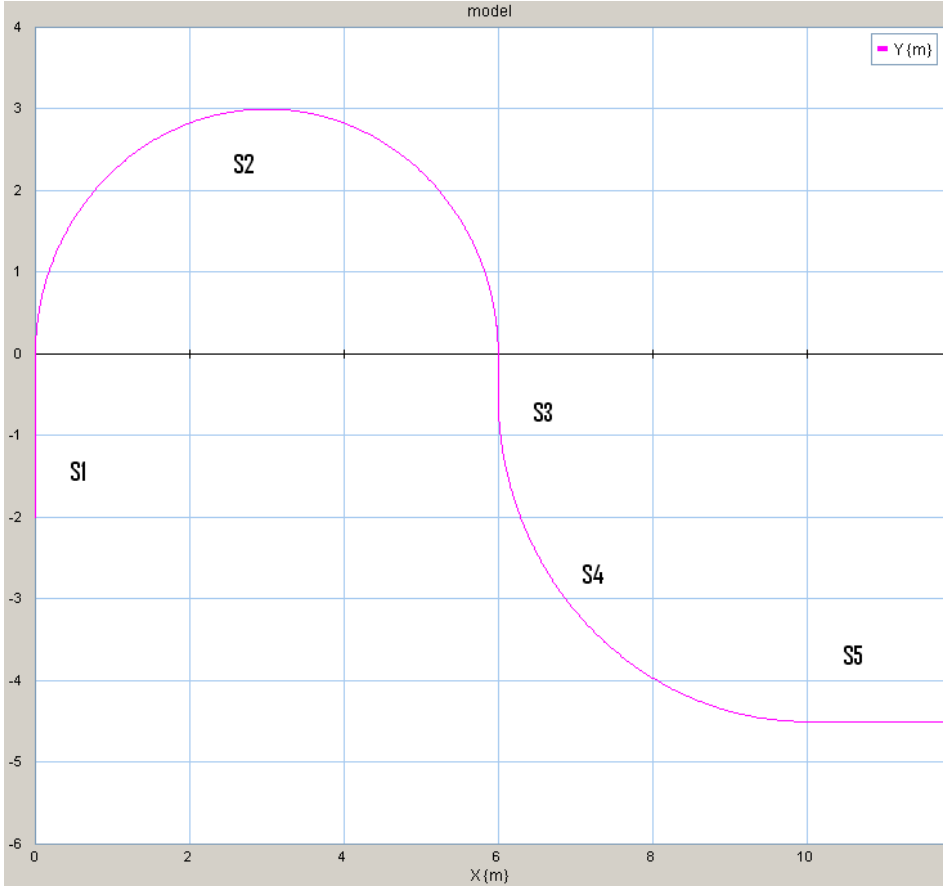
Co-Simulation

Export Tool Wrapper FMU

Agenda

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

```
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

```
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

```
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;
```

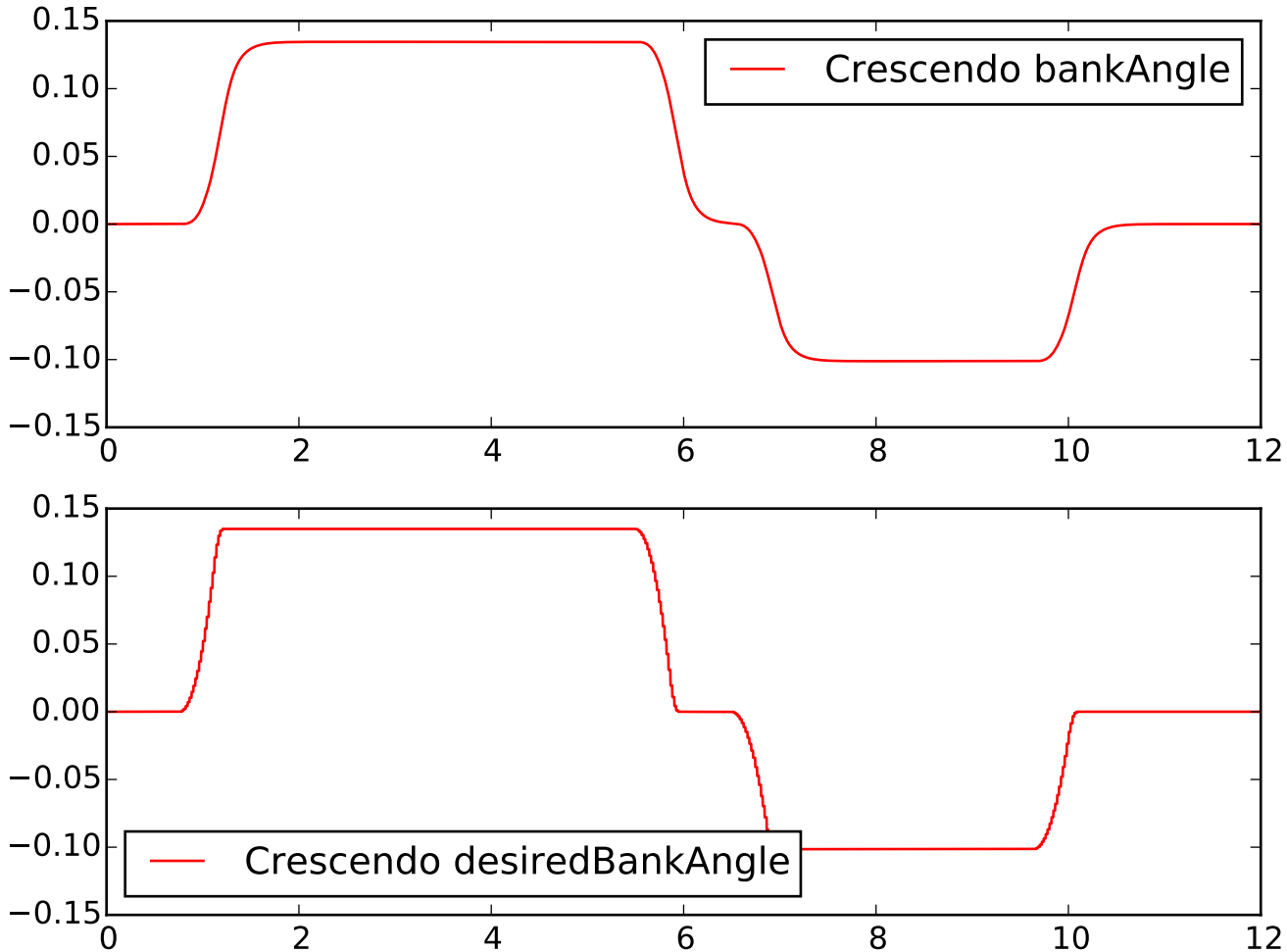
Case-Study

DESTECS Contract

```
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;
```

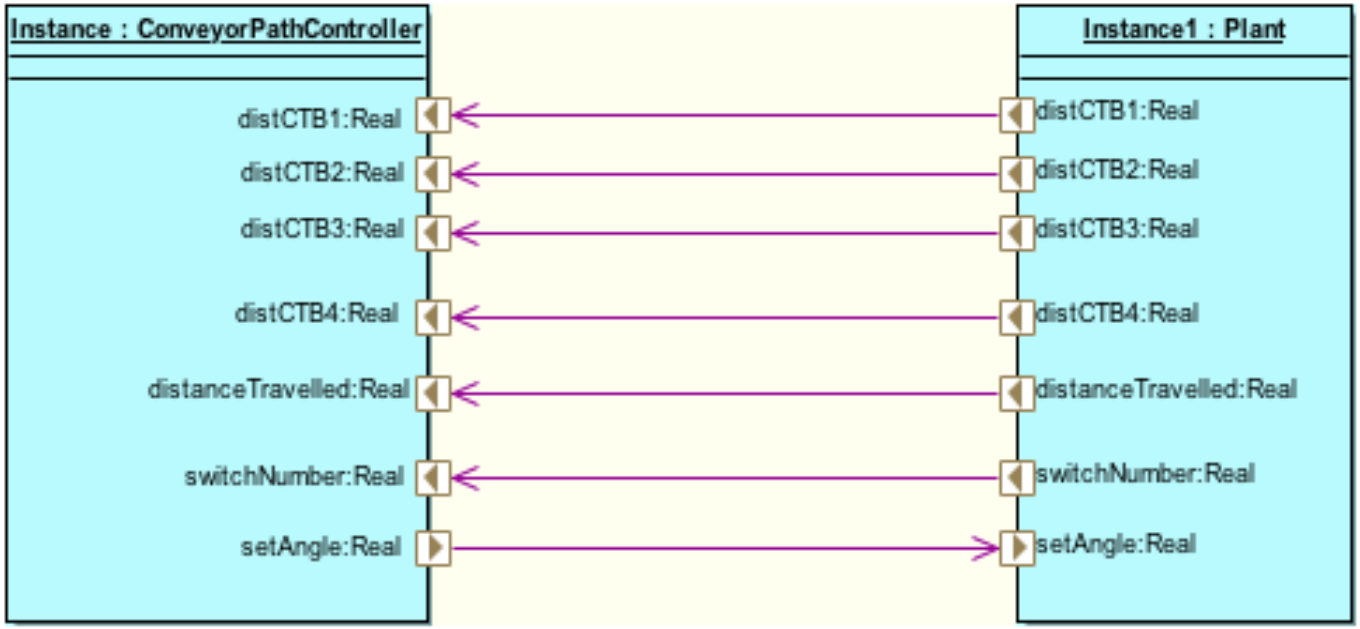
Case-Study

DESTECS Simulation - result



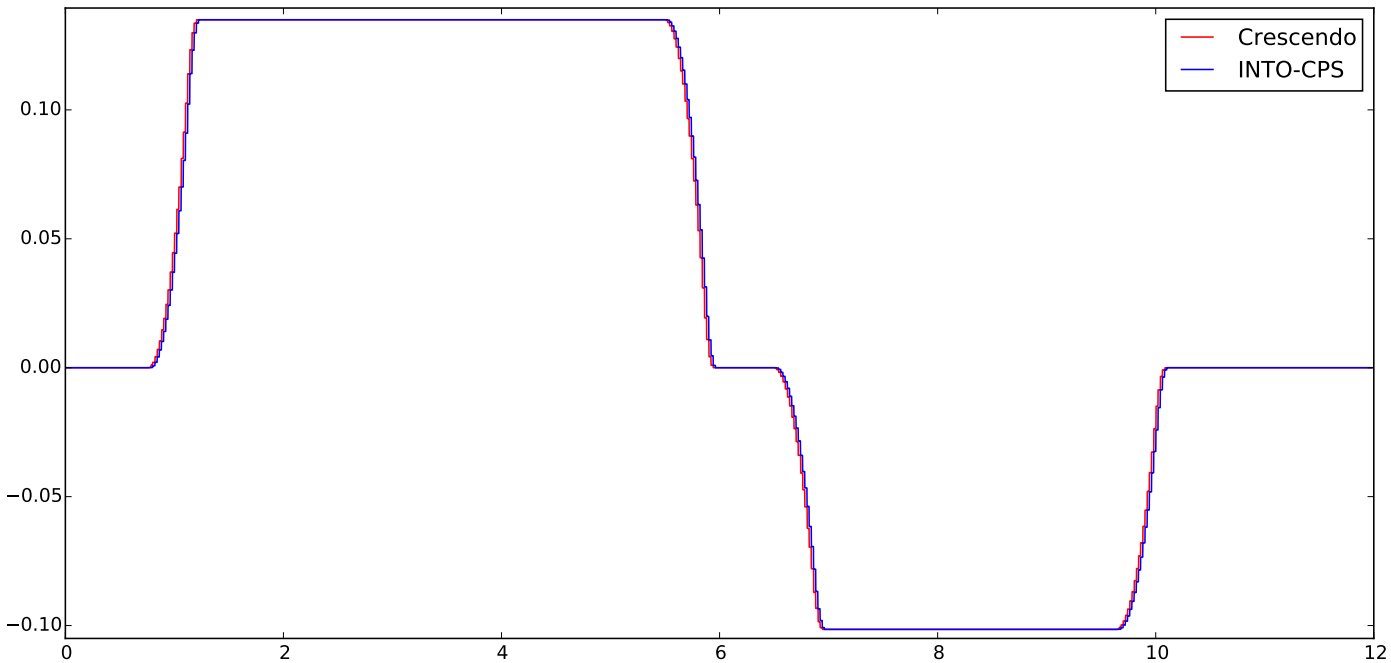
Case-Study

INTO-CPS



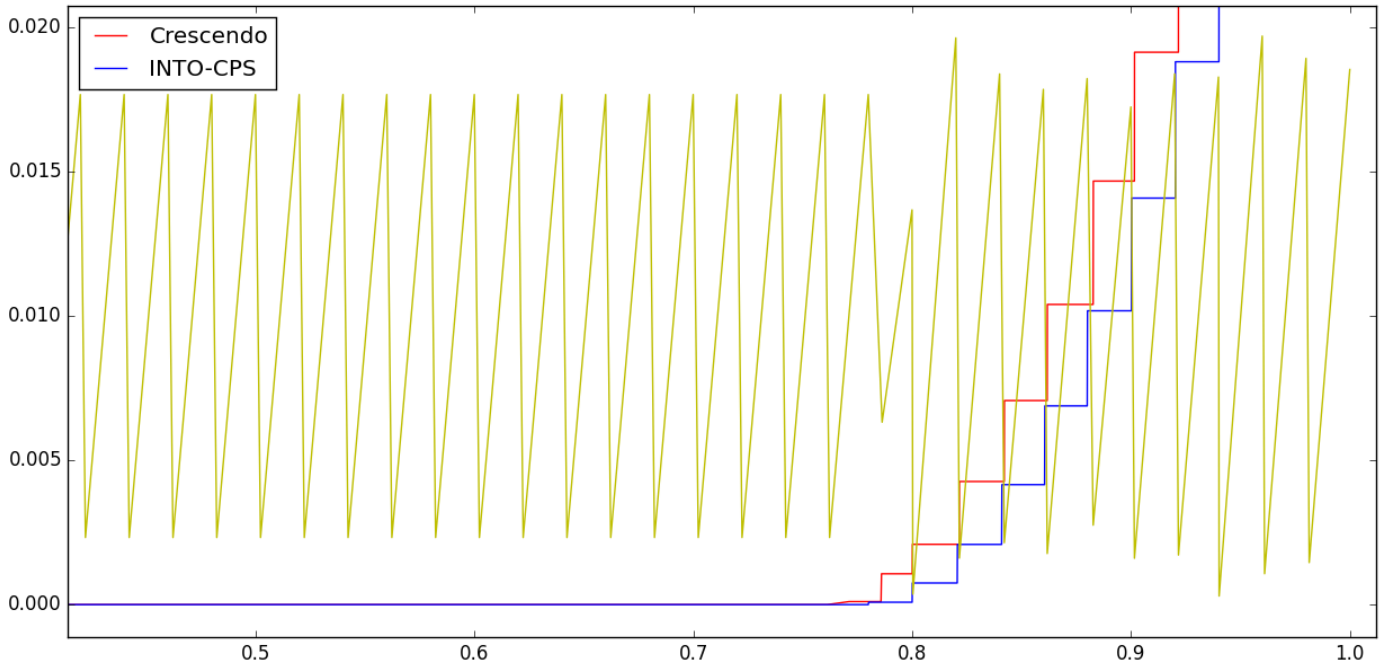
Case-Study

INTO-CPS Simulation - result



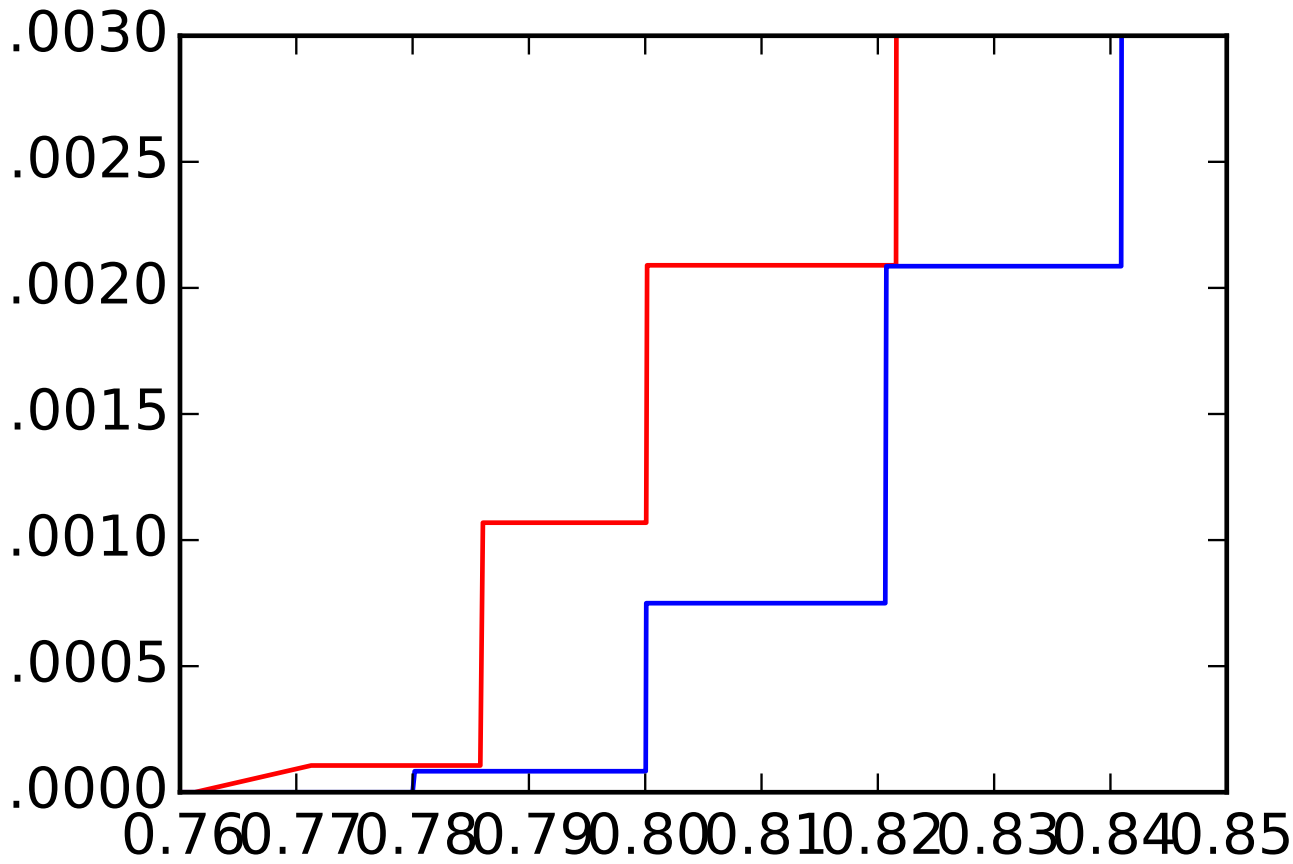
Case-Study

INTO-CPS Simulation - result



Case-Study

INTO-CPS Simulation - result



Agenda

Technologies

Tool Extensions

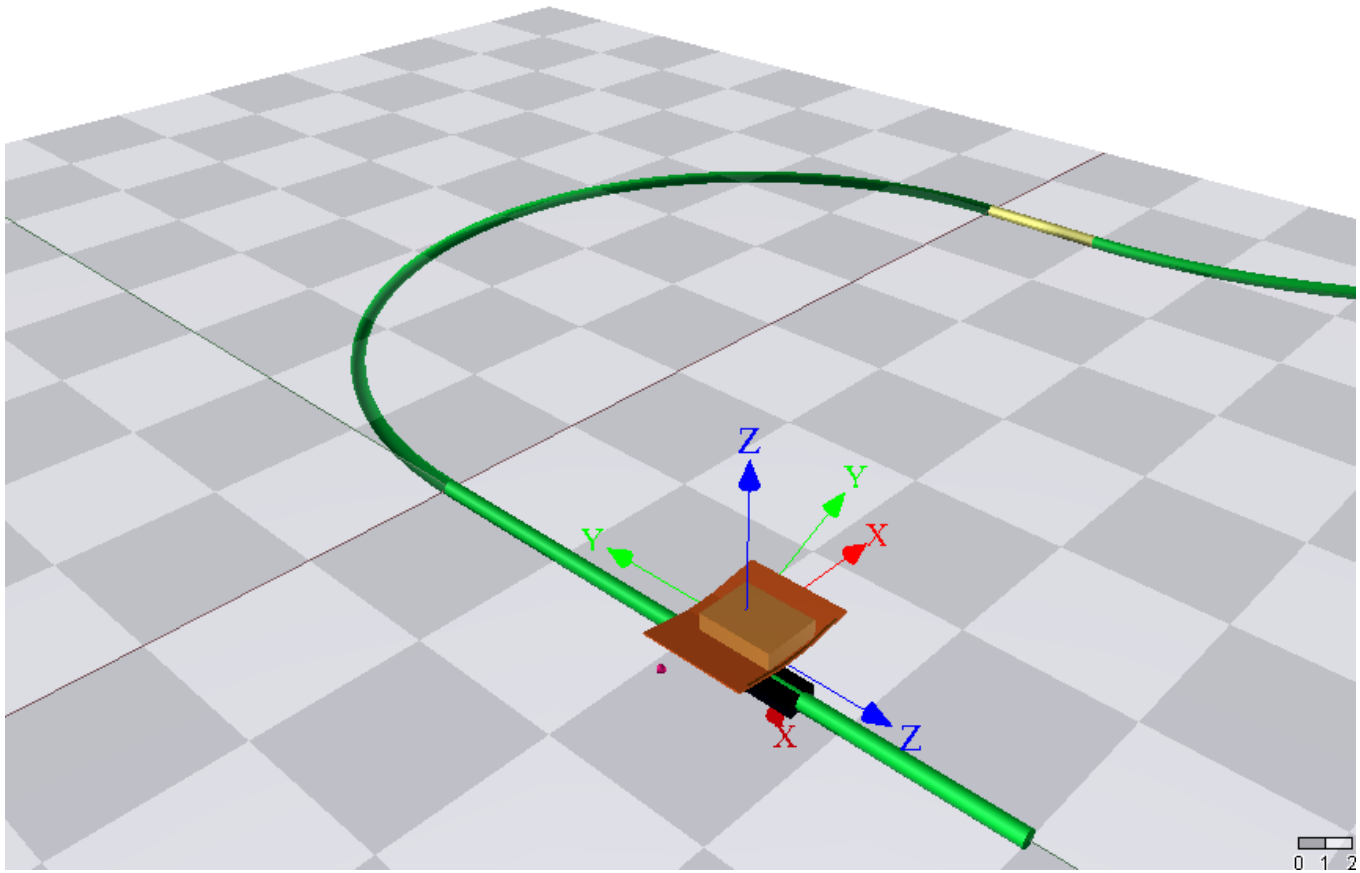
Case-Study

Animation

Conclusion and future plans

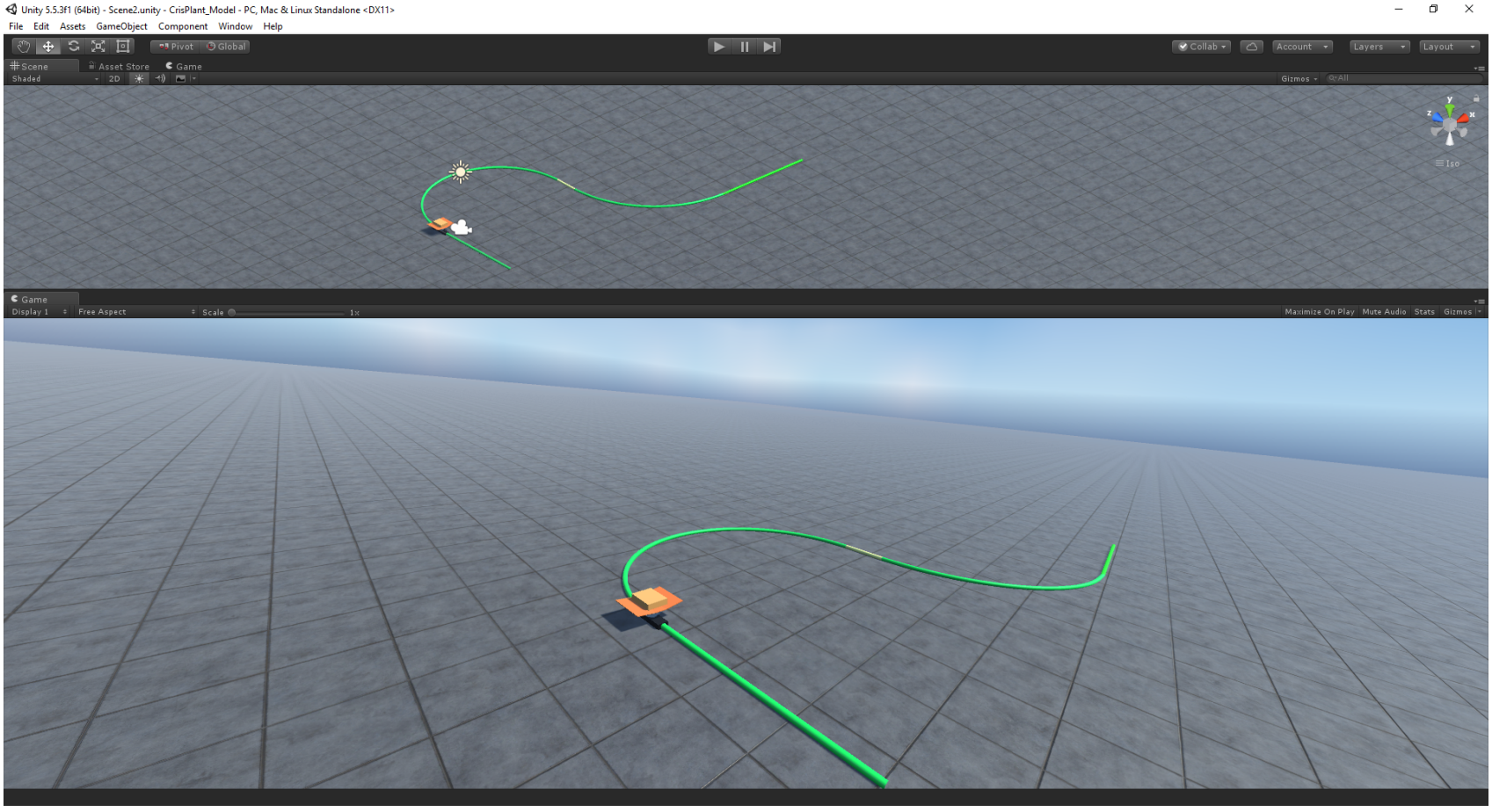
Animation

20sim 3D Animation



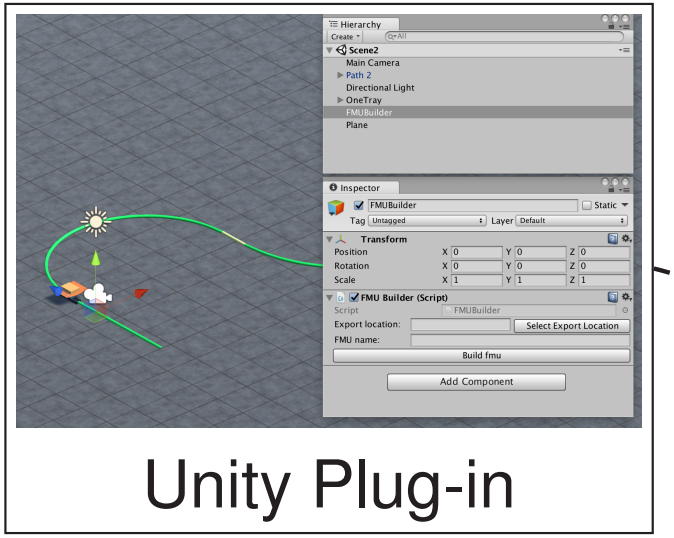
Animation

Automated conversion to Unity



Animation

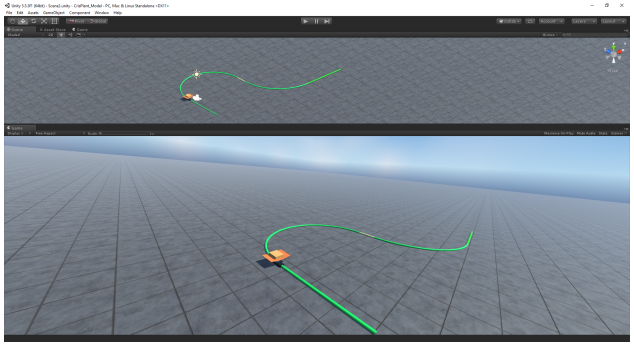
Unity FMI Support



Unity Plug-in

Export Tool Wrapper FMU
Generate:

- unity excitable (`.exe`)
- `modelDescription.xml`



Unity Executable

Socket

FMU

FMI

Co-Simulation

Demo

https://youtu.be/zHIcLxf-RVI

Agenda

Technologies

Tool Extensions

Case-Study

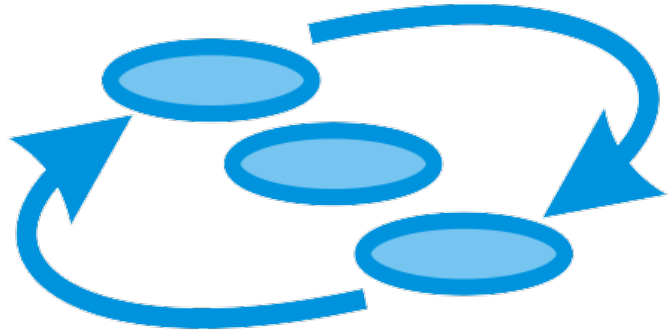
Animation

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