

**SHORT NOTES**

**AnyLogic 4.0: Simulating Hybrid Systems with Extended UML-RT**

We outline a modelling approach aimed to capture sophisticated interdependencies of discrete and continuous behaviors in hybrid systems. The approach is essentially a hybrid extension of widely recognized object-oriented languages UML and UML-RT. It is fully supported by a new simulation tool AnyLogic 4.0 from Experimental Object Technologies [www.xjtek.com].

**Hybrid Statecharts**

The concept of hybrid statecharts naturally integrating discrete logic and continuous time dynamics has been around for quite a while, see for example [1], but its commercial implementation was missing until recently.

In addition to standard UML attributes of states and transitions, in hybrid statecharts you can associate a set of differential and algebraic equations with a simple and/or composite state of a statechart, and you can also specify a condition over continuously changing variables as a trigger of a transition. The currently active set of equations and triggers is defined by the current simple state and all its containers.

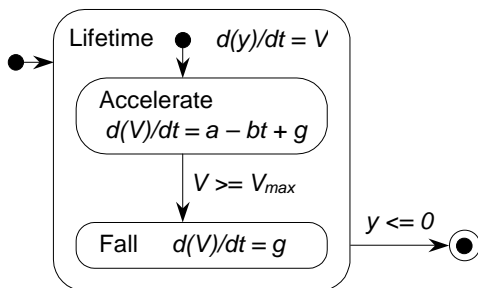


Fig. 1 : A Hybrid Statechart

The example hybrid statechart in Fig. 1 is a simple model of an object that accelerates vertically up until it reaches the speed of  $V_{max}$ , and then falls under the impact of gravity until it touches the ground ( $y \leq 0$ ), where it ceases to exist.

**Extended UML-RT Structure Diagram**

Being widely accepted as systems design standard, UML is almost ignored by professional simulation tools, partially due to their vendors' legacy problems, partially because UML so-to-say "lacks semantics" needed to generate executable models.

UML-RT, a real-time branch of UML, is better in the last respect, and it was taken as a basis for our approach. The key building block of hierarchical, object-oriented UML-RT model is active object. Objects

can encapsulate other objects and host activities, e.g. statecharts, see Fig. 2. Objects interact by exchanging messages through ports and (here we extend UML-RT) by linking continuously changing inputs and outputs (in the current version these links are unidirectional).

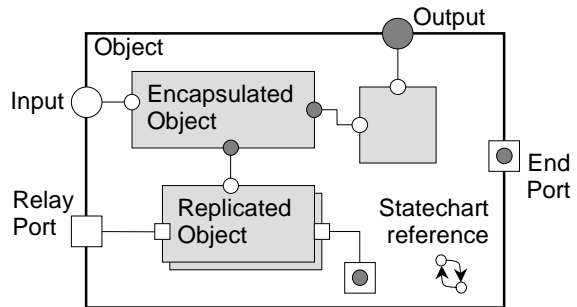


Fig. 2 : A Structure Diagram

In most challenging real life systems everything is dynamic, including structure and interconnection of components. The approach we have developed and implemented captures limited lifetime and mobility of objects: objects can be created and destroyed as the system evolves, and connected and disconnected from each other dynamically.

**AnyLogic Environment**

AnyLogic model editor (Fig. 3) is a Windows application with complete set of UI features. Besides using graphical languages of statecharts and structure diagrams, the user can write Java code and add arbitrary Java modules: the tool is open at this level. The editor generates a 100% Java executable model, which can run over the Web.

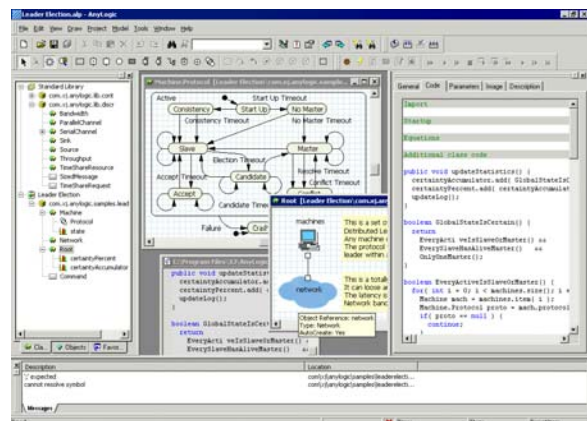
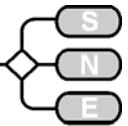


Fig. 3 : AnyLogic Model Editor

AnyLogic allows you to debug models in terms of original diagrams. You can step, play and run the model, view objects and change variables at any



level, define graphical breakpoints, etc. The debugger can connect to the model remotely via TCP.

The hybrid simulation engine of AnyLogic, also written in Java, see [2], handles dynamically changing sets of algebraic-differential equations (both stiff and non-stiff), checks their correctness, detects and breaks algebraic loops.

The preview version of AnyLogic is available at the web site [www.xjtek.com](http://www.xjtek.com). AnyLogic 4.0 release version contains object-centric animation development facilities and optional fast native code numerical engine for Windows platform.

### References

- [1] O. Maler, Z. Manna, A. Pnueli - *From timed to hybrid systems*, In *Proc. of REX workshop "Real-Time: Theory in Practice"*, Springer-Verlag, 1992.
- [2] A. Borshchev, Yu. Kolesov, Yu. Senichenkov - *Java Engine For UML Based Hybrid State Machines*, In *Proc. of the 2000 Winter Simulation Conference*.

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