Slide 0

Chap.7 Basic Formalisms: Coupled Multicomponent Systems

Introduction

Slide 1

- system specification of multicomponent and network of systems
  - allow us to model systems by composing smaller systems together
  - multicomponent system specification
    - composition is done nonmodularly
    - one component's state transitions can directly change another component's state
  - network of systems specification
    - a means to couple stand-alone systems by connecting their output and input interfaces
  - closed under coupling
    - coupling of systems defines a basic system in the same formalism
    - make a larger coupled system with hierarchical, modular construction

Discrete event specified network formalism (DEVN)

Slide 2

- DEVN (DEVS coupled model specification)
  - provide a basis for modular construction of discrete event models
  - modularity is more natural for distributed simulation and supports reuse
- classic DEVS coupled models

  $N =< X, Y, D, \{M_d\}, \{I_d\}, \{Z_{i,d}\}, Select >$,

  with

  X a set of input events

  Y a set of output events

  D a set of component references

  * for each $d \in D$

    M_d is a classic DEVS model

  * for each $d \in D \cup \{N\}$,

    I_d is the influencer set of $d : I_d \subseteq D \cup \{N\}, d \notin I_d$,

Discrete event specified network formalism (DEVN) (Cont'd)

Slide 3

  * and for each $i \in I_d$,

    $Z_{i,d}$ is a function, the $i-$to$-d$ output translation with

    $Z_{i,d} : X \rightarrow X_d$, if $i = N$

    $Z_{i,d} : Y_i \rightarrow Y$, if $d = N$

    $Z_{i,d} : Y_i \rightarrow X_d$, if $d \neq N$ and $i \neq N$

    $Select : 2^D - \{\} \rightarrow D$, the tie-breaking function

Discrete event specified network formalism (DEVN) (Cont'd)

Slide 4

- closure under coupling of classic DEVS
  - given a coupled model, N, with classic DEVS components, we associate with it a basic DEVS

    $DEVS_N =< X, Y, S, \delta_{ext}, \delta_{int}, \lambda, ta >$

    where

    $S = \times_{d \in D} Q_d$
    and $ta : S \rightarrow \Re_0^+ \cup \{\infty\}$ is defined by
    $ta(s) = minimum\{\sigma_d | d \in D\}$, where $\sigma_d = ta_d(s_d) - e_d$
  - let the set of *imminents* $IMM(s) = \{d | d \in D \wedge \sigma_d = ta(s)\}$
  - let $d^* = Select(IMM(s))$ be selected component for executing output and internal transition functions

Discrete event specified network formalism (DEVN) (Cont'd)

Slide 5

- we define $\delta_{int} : S \rightarrow S$
  * let $s = (\ldots, (s_d, e_d), \ldots)$, then $\delta_{int}(s) = s' = (\ldots, (s'_d, e'_d), \ldots)$, where

$$
\begin{aligned}
(s'_d, e'_d) &= (\delta_{int,d}(s_d), 0) && \text{if } d = d^* \\
&= (\delta_{ext,d}((s_d, e_d + ta(s)), x_d), 0) && \text{if } d^* \in I_d \text{ and } x_d = \varnothing \\
&= (s_d, e_d + ta(s)) && \text{otherwise,}
\end{aligned}
$$

where $x_d = Z_{d^*,d}(\lambda_{d^*}(s_{d^*}))$

Discrete event specified network formalism (DEVN) (Cont'd)

Slide 6

- we define $\delta_{ext} : Q \times X \rightarrow S$ where $\delta_{ext}((s,e),x) = s' = (\ldots,(s'_d, e'_d),\ldots)$ by

$$\begin{aligned}(s'_d, e'_d) &= (\delta_{ext,d}((s_d, e_d + e), x_d), 0) && \text{if } N \in I_d \;\&\; x_d \neq \varnothing \\ &= (s_d, e_d + e) && \text{otherwise,}\end{aligned}$$

  where $x_d = Z_{N,d}(x)$

- we define the resultant output function, $\lambda : S \rightarrow Y$

$$\begin{aligned}\lambda(s) &= Z_{d^*,N}(\lambda_{d^*}(s_{d^*})) && \text{if } d^* \in I_N \\ &= \varnothing && \text{otherwise,}\end{aligned}$$

Discrete event specified network formalism (DEVN) (Cont'd)

Slide 7

- parallel DEVS coupled models
  - almost identical to that for classic DEVS except for the absence of the Select function

    $N =< X, Y, D, \{M_d\}, \{I_d\}, \{Z_{i,d}\} >$

    with X, Y, D, I_d, and $Z_{i,d}$ having the same interpretation as for Classic DEVS coupled models and for each d in D, M_d is a parallel DEVS model
- closure under coupling of parallel DEVS
  - a resultant parallel DEVS: $DEVS_N =< X, S, Y, \delta_{int}, \delta_{ext}, \delta_{con}, \lambda, ta >$
    - the state set is a crossproduct, $S = \times_{d \in D} Q_d$
    - time advance function, $ta(s) =$ minimum$\{\sigma_d | d \in D\}$, where $s \in S$ and $\sigma_d = ta(s_d) - e_d$
  - $IMM(s)$ are the imminent components and all imminents will be activated
    * $INT(s)$ is the subset of the imminents that have no input messages
    * $EXT(s)$ contains the components receiving input events but not scheduled for an internal transition

Discrete event specified network formalism (DEVN) (Cont'd)

Slide 8

* $CONF(s)$ contains the components receiving input events and also scheduled for internal transitions at the same time
* $UN(s)$ contains the remaining components
* $IMM = \{d|\sigma_d = ta(s)\}$ (the imminent components)
* $INF(s) = \{d|i \in I_d, i \in IMM(s) \wedge x_d^b \neq \Phi\}$, where $x_d^b = \{Z_{i,d}(\lambda_i(s_i))|i \in IMM(s) \cap I_d\}$ (components about to receive inputs)
* $CONF(s) = IMM(s) \cap INF(s)$ (confluent components)
* $INT(s) = IMM(s) - INF(s)$ (imminent components receiving no input)
* $EXT(s) = INF(s) - IMM(s)$ (components receiving input but not imminent)
* $UN(s) = D - IMM(s) - INF(s)$

– output function

* collecting all the external outputs of the imminents in a bag
* $\lambda(s) = \{Z_{d,N}(\lambda_d(s_d))|d \in IMM(s) \wedge d \in I_N\}$

Discrete event specified network formalism (DEVN) (Cont'd)

Slide 9

– internal transition function

* four kinds of component transitions
  - internal transitions $INT(s)$ components
  - external transitions $EXT(s)$ components
  - confluent transitions $CONF(s)$ components
  - the remainder $UN(s)$ components
* $\delta_{int}(s) = (\ldots, (s_d^{'}, e_d^{'}), \ldots)$,
  where

$$
\begin{aligned}
(s_d^{'}, e_d^{'}) &= (\delta_{int,d}(s_d), 0) && \text{for } d \in INT(s)),\\
(s_d^{'}, e_d^{'}) &= (\delta_{ext,d}(s_d, e_d + ta(s), x_d^b), 0) && \text{for } d \in EXT(s)),\\
(s_d^{'}, e_d^{'}) &= (\delta_{con,d}(s_d, x_d^b), 0) && \text{for } d \in CONF(s)),\\
(s_d^{'}, e_d^{'}) &= (s_d, e_d + ta(s)) && \text{otherwise}
\end{aligned}
$$

Discrete event specified network formalism (DEVN) (Cont'd)

Slide 10

- external transition function
  - $\delta_{ext}(s, e, x^b) = (\ldots, (s'_d, e'_d), \ldots)$,
    where $0 < e < ta(s)$ and

$$\begin{aligned} (s'_d, e'_d) &= (\delta_{ext,d}(s_d, e_d + e, x^b_d), 0) && \text{for } N \in I_d \wedge x^b_d \neq \Phi \\ (s'_d, e'_d) &= (s_d, e_d + e) && \text{otherwise} \end{aligned}$$

    where $x^b_d = \{Z_{N,d}(x) | x \in x^b \wedge N \in I_d\}$

Discrete event specified network formalism (DEVN) (Cont'd)

Slide 11

- confluent transition function
  - let $INF'(s) = \{d | (i \in I_d, i \in IMM(s) \vee N \in I_d) \wedge x^b_d \neq \Phi\}$, where
    $x^b_d = \{Z_{i,d}(\lambda_i(s_i)) | i \in IMM(s) \wedge i \in I_d\} \cup \{Z_{N,d}(x) | x \in x^b \wedge N \in I_d\}$
  - $CONF'(s) = IMM(s) \cap INF'(s)$
  - $INT'(s) = IMM(s) - INF'(s)$
  - $EXT'(s) = INF'(s) - IMM(s)$
  - $\delta_{con}(s, x^b) = (\ldots, (s'_d, e'_d), \ldots)$,
    where

$$\begin{aligned} (s'_d, e'_d) &= (\delta_{int,d}(s_d), 0) && \text{for } d \in INT'(s), \\ (s'_d, e'_d) &= (\delta_{ext,d}(s_d, e_d + ta(s), x^b_d), 0) && \text{for } d \in EXT'(s)), \\ (s'_d, e'_d) &= (\delta_{con,d}(s_d, x^b_d), 0) && \text{for } d \in CONF'(s)), \\ (s'_d, e'_d) &= (s_d, e_d + ta(s)) && \text{otherwise} \end{aligned}$$