Stochastic Process Algebra Based Software Process Simulation Modeling

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Outline

- Motivation
- Simulation: Step by Step
- Conclusion

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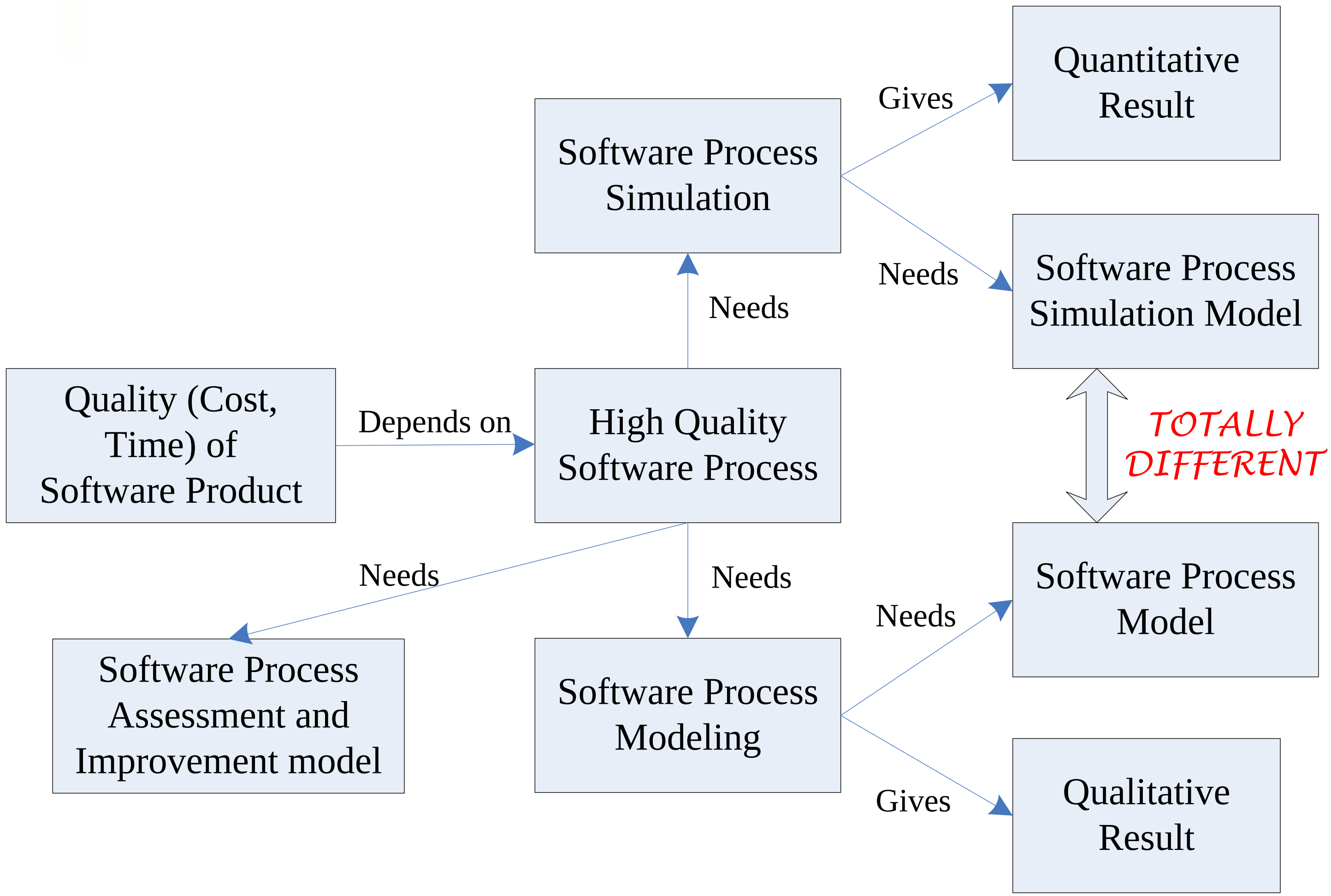
Why Modeling or Simulation?



Two Models Needed to build, because:

- Software process model
  - Based on various technologies
    - Software design notation
    - Formal method
    - Multi-agents system
    - ……
- Software process simulation model
  - Based on simulation technologies
    - System dynamic (SD)
    - Discrete event simulation (DES)

To Uniform the Two Models

- s-TRISO/ML language has been introduced
  - Derive simulation model from process model
  - Only one model needs to be built
  - Stochastic process algebra based approach
  - Simulate uncertainties on time of a process
  - Give time related simulation results

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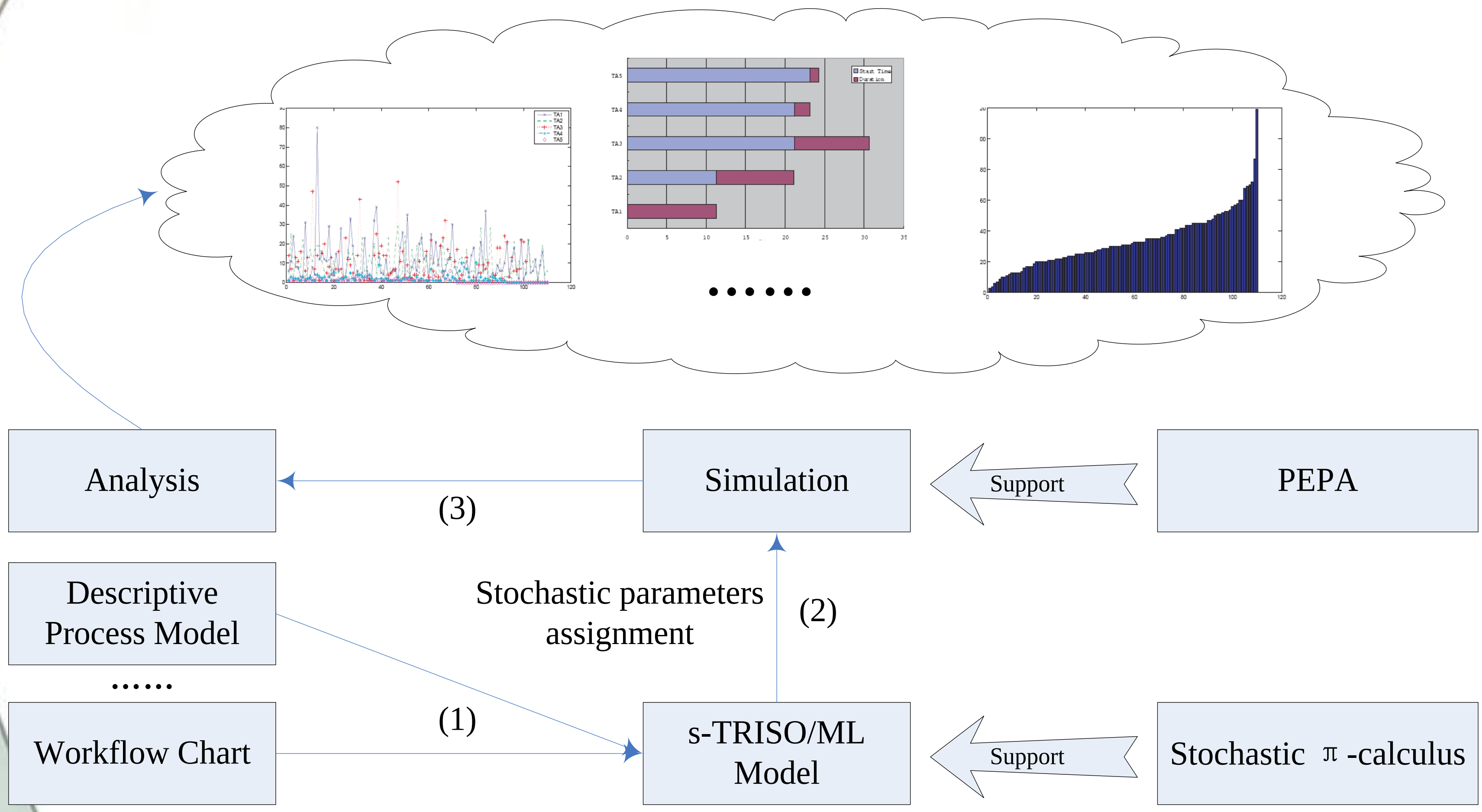
Framework



Analysis
(3)
Simulation
Support
PEPA
Descriptive Process Model
Stochastic parameters assignment
(2)
……
Workflow Chart
(1)
s-TRISO/ML Model
Support
Stochastic π -calculus

Simulation: Step by Step

- Describe process by s-TRISO/ML
- Transform s-TRISO/ML into stochastic π-calculus by the mapping rules
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Stochastic Polyadic π-Calculus

- Definition: The syntax of the stochastic polyadic π-calculus is given in the following BNF equations:

$$P := M \mid P \,|\, P' \mid (\nu z)P \mid !P$$

$$M := 0 \mid \pi.P \mid M + M'$$

$$\pi := \overline{x}\langle \tilde{y} \rangle \mid x(\tilde{z}) \mid (\tau, r) \mid [x = y]\pi$$

- The most important is unobserved action:

$$(\tau, r)$$

In (τ, r)……

- τ is the invisible action
- r is the stochastic parameter of the action
  - $r \in (0, +\infty)$ is a parameter of the negative exponential distribution govern its duration
  - Imply the time it takes to complete the action
  - $+\infty$ means the expected time of the action should be small enough, or instantaneously
  - 0 means the expected time of the action should be large enough, or it cannot be finished

Simulation: Step by Step

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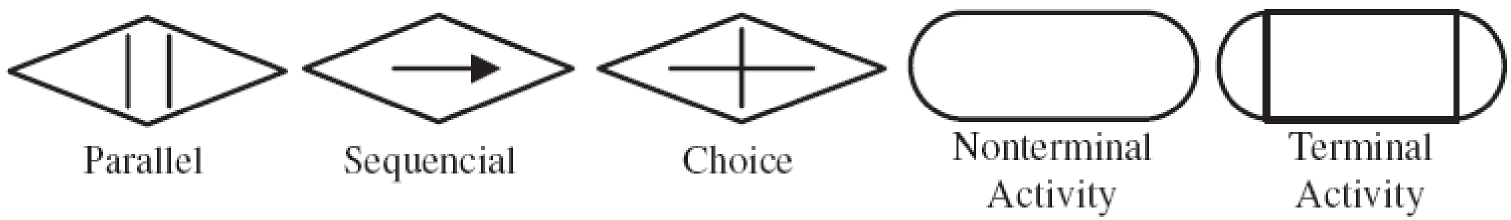
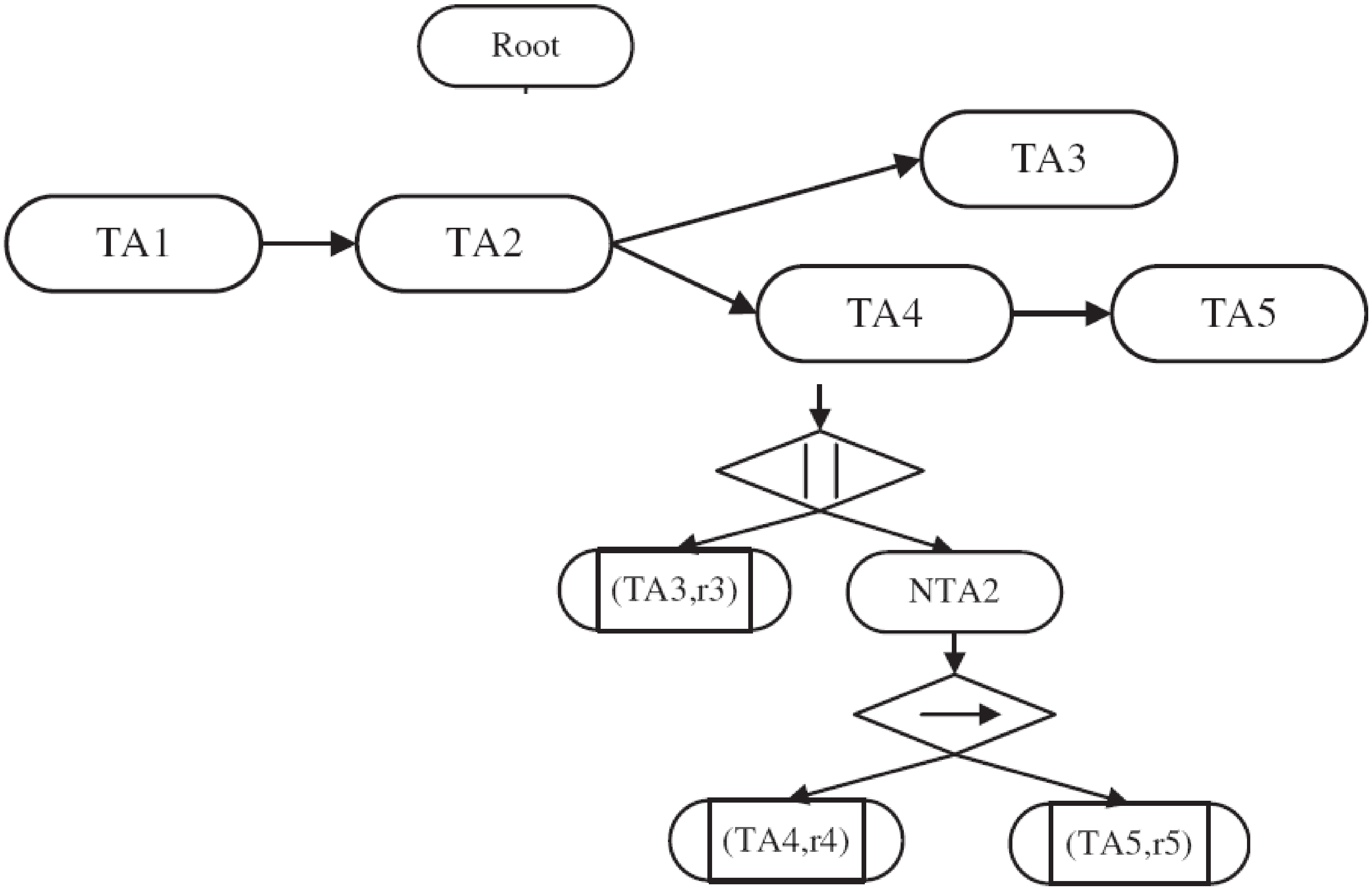
Graphical Notation of s-TRISO/ML



Example: s-TRISO/ML Graph



Simulation: Step by Step

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Mapping Rules in s-TRISO/ML

Rule 1 For an actor with the unique identifier ac, the stochastic polyadic π-calculus process for it has the following form:

$$A_{ac} \stackrel{def}{=} assign_{ac}(start, end).\overline{start}.end.A_{ac}|A_{ac}$$

Rule 2 For an activity $a \in \mathcal{A}$, it receives $\{b_{11}, \cdots, b_{1m}\}, \cdots, \{b_{l1}, \cdots, b_{ln}\}$ from the channels $\{chi_1, \cdots, chi_l\}$ and $\{p_1, \cdots, p_u\}$ from the channel $ex_{a_p\_a}$, sends $\{c_{11}, \cdots, c_{1s}\}, \cdots, \{c_{r1}, \cdots, c_{rt}\}$ through the channels $\{cho_1, \cdots, cho_r\}$, and returns $\{q_1, \cdots, q_v\}$ to its parent a_p through the channel $ex_{a\_a_p}$. Then, the stochastic polyadic π-calculus process A_a for the activity is:

$$A_a \stackrel{def}{=} (\nu\ i_1, \cdots, i_l, i_o)(I_{a_s}\langle i_1, \cdots, i_l\rangle\ |E_a\langle i_1, \cdots, i_l, i_o\rangle \mid O_a\langle i_o\rangle)$$

$$I_a \stackrel{def}{=} (i_1, \cdots, i_l).chi_1(b_{11}, \cdots, b_{1m}).\bar{i}_1\langle b_{11}, \cdots, b_{1m}\rangle | \cdots | \; chi_l(b_{l1}, \cdots, b_{ln}).\bar{i}_l\langle b_{l1}, \cdots, b_{ln}\rangle.ex_{a_p\_a}(p_1, \cdots, p_v)$$

$$O_a \stackrel{def}{=} (i_o).i_o(c_{11}, \cdots, c_{1s}, \cdots, c_{r1}, \cdots, c_{rt}, q_1, \cdots, q_v).\overline{cho_1}\langle c_{r1}, \cdots, c_{rs}\rangle. \cdots .\overline{cho_r}\langle c_{r1}, \cdots, c_{rt}\rangle.\overline{ex_{a\_a_p}}\langle q_1, \cdots, q_v\rangle$$

Mapping Rules in s-TRISO/ML

Rule 3 For a non-terminal activity $a \in \mathcal{A}$, it is refined to w sequential activities, $a_1, \cdots, a_w$. Each sub-activity may specify the information exchanges with its parent. For example, the wth sub-activity will receive $\{p_{w1}, \cdots, p_{wj}\}$ from the activity a and returns $\{q_{w1}, \cdots, q_{wk}\}$. The activity will be assigned to the actor with the unique identifier ac. Then the E_a process for the activity a is:

$$\begin{aligned} E_a = {} & (i_1, \cdots, i_l, i_o).i_1(b_{11}, \cdots, b_{1m}). \cdots .i_l(b_{l1}, \cdots, b_{ln}).ex_{a_p\_a}(p_1, \cdots, p_u). \\ & trigger_a.\overline{assign_{ac}}\langle start_a, end_a\rangle.start_a.\overline{ex_{a\_a1}}\langle p_{11}, \cdots, p_{1h}\rangle.\overline{trigger_{a1}}. \\ & ex_{a1\_a}(q_{11}, \cdots, q_{1i}).triggered_{a1}. \cdots .\overline{ex_{a\_aw}}\langle p_{w1}, \cdots, p_{wj}\rangle.\overline{trigger_{aw}}. \\ & ex_{aw\_a}(q_{w1}, \cdots, q_{wk}).triggered_{aw}.\overline{triggered_a}.\overline{end_a}. \\ & \overline{i_o}\langle c_{11}, \cdots, c_{1s}, \cdots, c_{r1}, \cdots, c_{rt}, q_1, \cdots, q_v\rangle \end{aligned}$$

Mapping Rules in s-TRISO/ML

Rule 4 For a non-terminal activity $a \in \mathcal{A}$, it is decomposed into w concurrently combined activities. Then the E_a process for the activity a is:

$$\begin{aligned}
E_a =\ & (i, q, i_1, \cdots, i_l, i_o).(\nu k_{a1}, \cdots, k_{aw}) i_1(b_{11}, \cdots, b_{1m}). \cdots .i_l(b_{l1}, \cdots, b_{ln}). \\
& ex_{a_p_a}(p_1, \cdots, p_u).trigger_a.\overline{assign_{ac}}\langle start_a, end_a\rangle.start_a.(E_1|E_2) \\
E_1 =\ & (\overline{ex_{a_a1}}\langle p_{11}, \cdots, p_{1h}\rangle.\overline{trigger_{a1}}.ex_{a1_a}(q_{11}, \cdots, q_{1i}).triggered_{a1}.\overline{k_{a1}}. \\
& \overline{k_{a1}}\langle q_{11}, \cdots, q_{1i}\rangle) \mid \cdots \mid (\overline{ex_{a_aw}}\langle p_{w1}, \cdots, p_{wj}\rangle.\overline{trigger_{aw}}.ex_{aw_a}(q_{w1}, \cdots, q_{wk}). \\
& triggered_{aw}.\overline{k_{aw}}.\overline{k_{aw}}\langle q_{w1}, \cdots, q_{wk}\rangle) \\
E_2 =\ & k_{a1}.k_{a1}(q_{11}, \cdots, q_{1i}). \cdots .k_{a1}.k_{wa}(q_{w1}, \cdots, q_{wk}).\overline{triggered_a}.\overline{end_a}. \\
& \overline{i_o}\langle c_{11}, \cdots, c_{1s}, \cdots, c_{r1}, \cdots, c_{rt}, q_1, \cdots, q_v\rangle
\end{aligned}$$

Mapping Rules in s-TRISO/ML

Rule 5 For a non-terminal activity $a \in \mathcal{A}$, it is decomposed into w sub-activities, which are combined together through the choice operator. Then the E_a process for the activity a is:

$$
\begin{aligned}
E_a = {} & (i, q, i_1, \cdots, i_l, i_o).(\nu k)i_1(b_{11}, \cdots, b_{1m}). \cdots .i_l(b_{l1}, \cdots, b_{ln}). \\
& ex_{a_p\_a}(p_1, \cdots, p_u).trigger_a.\overline{assign_{ac}}\langle start_a, end_a\rangle.start_a.(E_1|E_2) \\
E_1 = {} & (\overline{ex_{a\_a1}}\langle p_1, \cdots, p_h\rangle.\overline{trigger_{a1}}.ex_{a1\_a}(q_1, \cdots, q_j).triggered_{a1}.\overline{k}.\overline{k}\langle q_1, \cdots, q_j\rangle) \\
& + \cdots + (\overline{ex_{a\_aw}}\langle p_1, \cdots, p_h\rangle.\overline{trigger_{aw}}.ex_{aw\_a}(q_1, \cdots, q_j).triggered_{aw}.\overline{k}. \\
& \overline{k}\langle q_1, \cdots, q_j\rangle) \\
E_2 = {} & k.k\langle q_1, \cdots, q_j\rangle.\overline{triggered_a}.\overline{end_a}.\overline{i_o}\langle c_{11}, \cdots, c_{1s}, \cdots, c_{r1}, \cdots, c_{rt}, q_1, \cdots, q_v\rangle
\end{aligned}
$$

Mapping Rules in s-TRISO/ML

Rule 6 For a terminal activity $a \in \mathcal{A}$, it is not decomposed further. Then the process E_a for the activity a is:

$$E_a = (i, q, i_1, \cdots, i_l, i_o).i_1(x_{11}, \cdots, x_{1m}). \cdots i_l(x_{l1}, \cdots, x_{ln}).ex_{a_p\_a}(p_1, \cdots, p_u).$$
$$trigger_a.\overline{assign_{ac}}\langle start_a, end_a\rangle.start_a.(\tau, r).\overline{ex_{a\_ap}}\langle p_1, \cdots, p_h\rangle.\overline{triggered_a}.$$
$$\overline{end_a}.\overline{i_o}\langle c_{11}, \cdots, c_{1s}, \cdots, c_{r1}, \cdots, c_{rt}, q_1, \cdots, q_v\rangle$$

Rule 7 The software process is defined as the concurrent combination of activities and actors:

$$SP = A_{a1} \mid \cdots \mid A_{am} \mid A_{ac1} \mid \cdots \mid A_{acn}$$

Simulation: Step by Step

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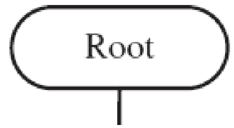
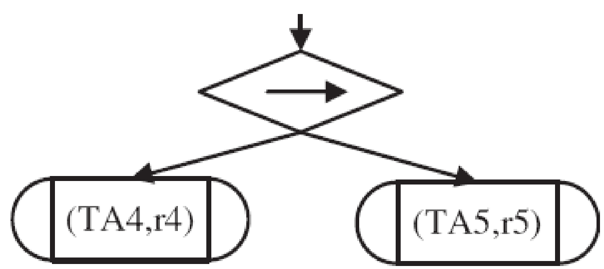
Assign the Stochastic Parameters

- Aim: To give a sound physical significance
- Historical data or experience should be considered to bridge model and simulation
  - Such as: $$r = \frac{P}{C \times S}$$
  - *P* stands for Productivity of the operator
  - *C* stands for Complexity of the activity
  - *S* stands for Scale of the activity

Example: Assign *r* in s-TRISO/ML



Activity	Type	Scale	Complexity	Productivity	r-value
TA1	requirement	20 pages	1	2 pages	0.1
TA2	design	5 pages	2	1 pages	0.1
TA3	coding/testing	10 KLOC	0.5	0.5 KLOC	0.1
TA4	coding	2 KLOC	0.5	0.5 KLOC	0.5
TA5	testing	1 KLOC	1	1 KLOC	1



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Simulation by PEPA

- PEPA is a stochastic process simulation tool
- Input the model and the assignment into PEPA, simulate for 110 times
- Input the model and new assignment into PEPA, simulate for 88 times
  - Replace the operator of TA2 by a new staff
  - The productivity is half of the primary one
  - r changes from 0.1 to 0.05
  - The rest parameters are still

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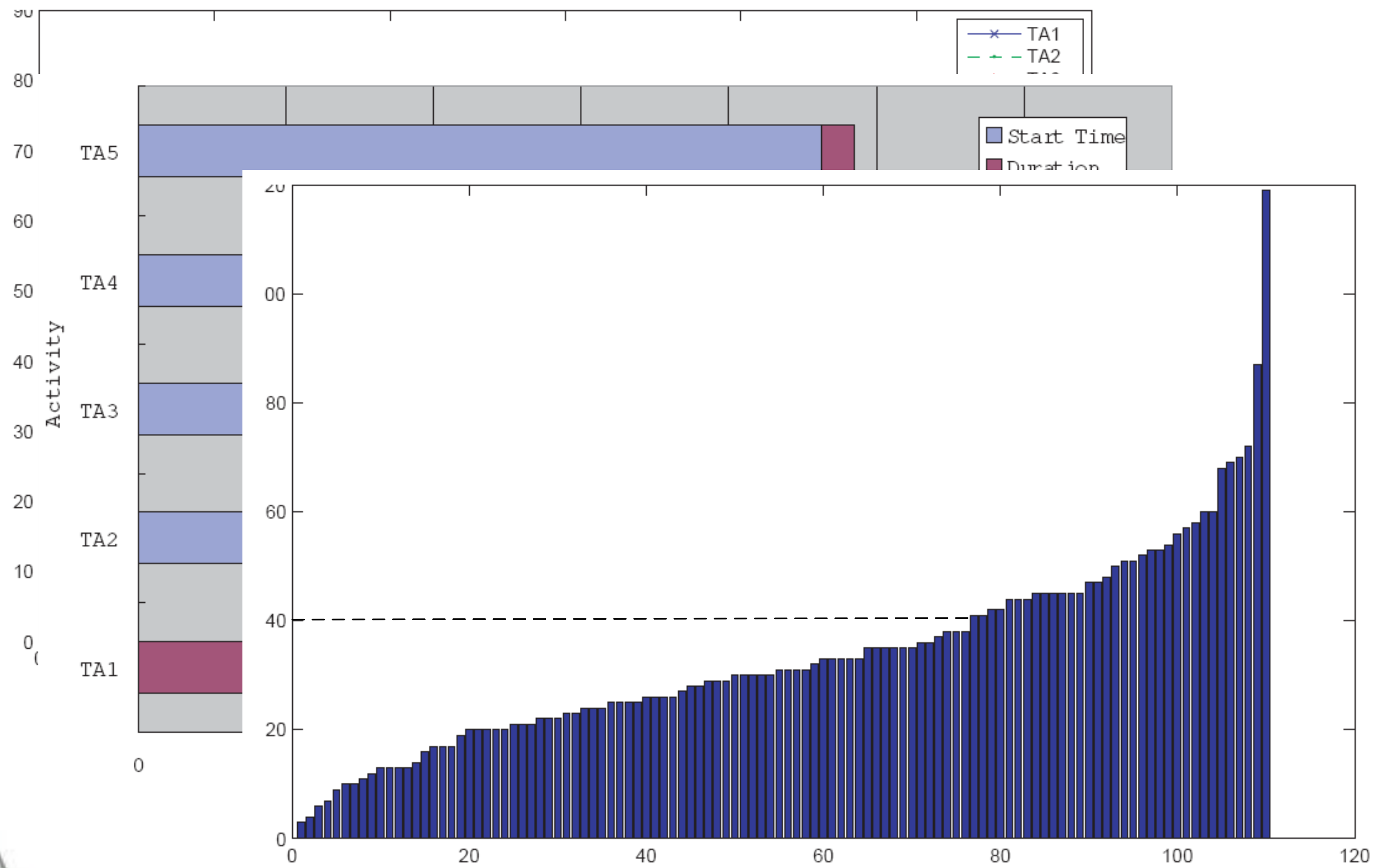
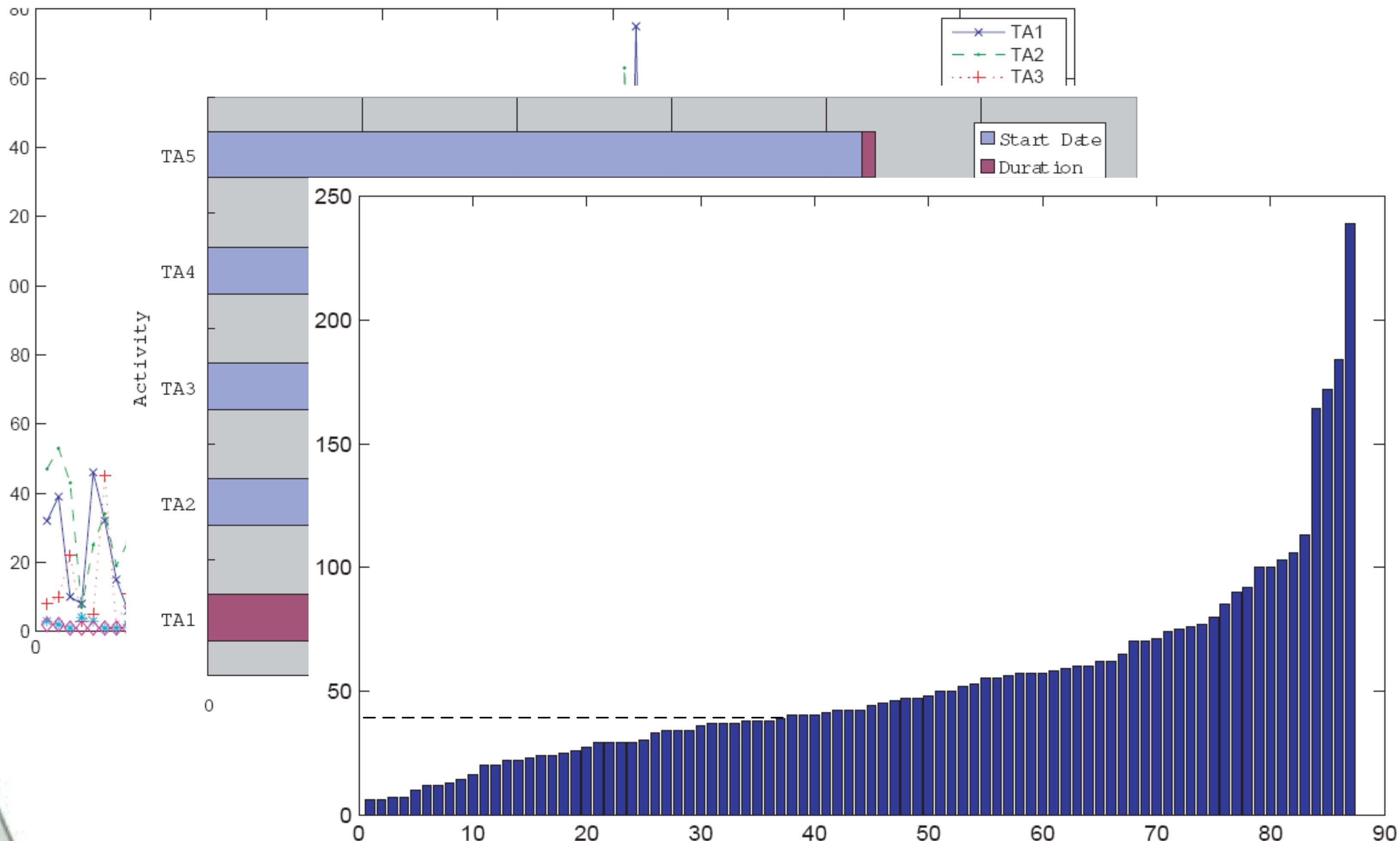
Analysis of the result

- Visualize the simulation result
- Average the execution time of each activity
- Sum the execution time of each times of simulation
  - Assume the requirement of the execution time be less than 40 days
- Compare the two rounds of simulation

Analysis of the result



Analysis of the result



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Conclusion

- Uniform the two process models for process description and process simulation
- Import the results of empirical study
- Introduce stochastic process algebra into software process simulation study
- Give simulation results about expected finishing time and process in-time/delay probability

Q & A

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