Entropy-Based Dynamic Complexity Metrics for Service-Oriented Systems

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Outline

- Background
- Entropy-based dynamic complexity metrics framework
- Two models and entropy definition
- Experimental analysis
- Conclusions

Background

- The complexity analysis of service system is mainly from the static aspect, and the dynamic complexity measurement has not attracted enough attention yet.
- Two core issues dynamic complexity metric for service system:
  - which factors to consider of the dynamic complexity of service system.
  - How to model dynamic complexity metrics of service system.

Background (cont.)

- Some metrics about the complexity of a service system have been deeply investigated from two aspects of control structure and information flow:
  - Control flow.
  - Data flow.
  - Interface.
- In difference, we consider that the dynamic complexity of a service system with execution traces .

Entropy-Based Dynamic Complexity Metrics Framework

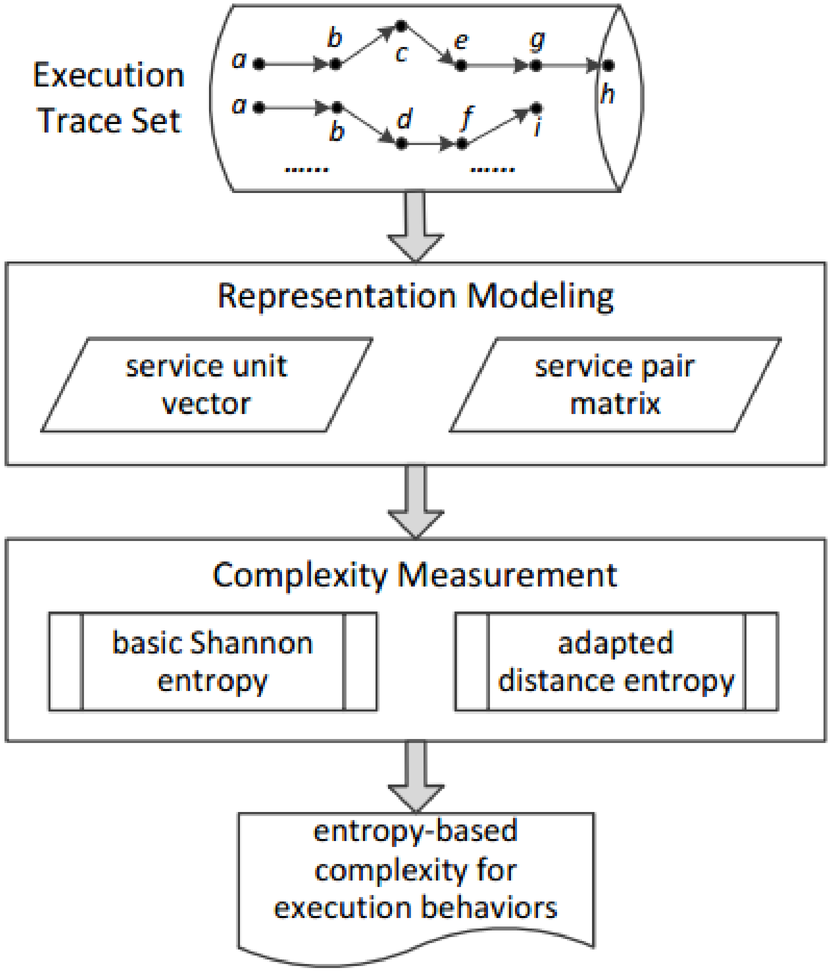


Fig. 1. The Overall Framework of Entropy-Based Complexity Measurement for the Dynamic Execution Behaviors of a Service System

Two Models and Entropy Definition

- Two Models for Execution Traces

Given a service system has six services, in which the services are from s_1 to s_6, T_1=< s_1, s_2, s_4, s_2, s_4, s_6 > and T_2=< s_1, s_5, s_6 > are two possible traces. Then the two traces can be represented to the corresponding ***service unit vector*** and ***service pair matrix*** models as below:

Categ.	Service unit vector					
	s_1	s_2	s_3	s_4	s_5	s_6
T_1	1	1	0	1	0	1
T_2	1	0	0	0	1	1

Service pair matrix						
	s_1	s_2	s_3	s_4	s_5	s_6
s_1	0	1	0	0	1	0
s_2	0	0	0	1	0	0
s_3	0	0	0	0	0	0
s_4	0	1	0	0	0	1
s_5	0	0	0	0	0	1
s_6	0	0	0	0	0	0

Two Models and Entropy Definition (cont.)

- Two definition of entropy:

  1) Shannon Entropy

$$H_s = -\sum_{i=1}^{m} p_i \cdot \log p_i. \qquad (1)$$

in which, m is the number of trace category in real application scenarios, for each trace category, its occurrence probability can be counted as p_i $(1 \leq i \leq m)$.

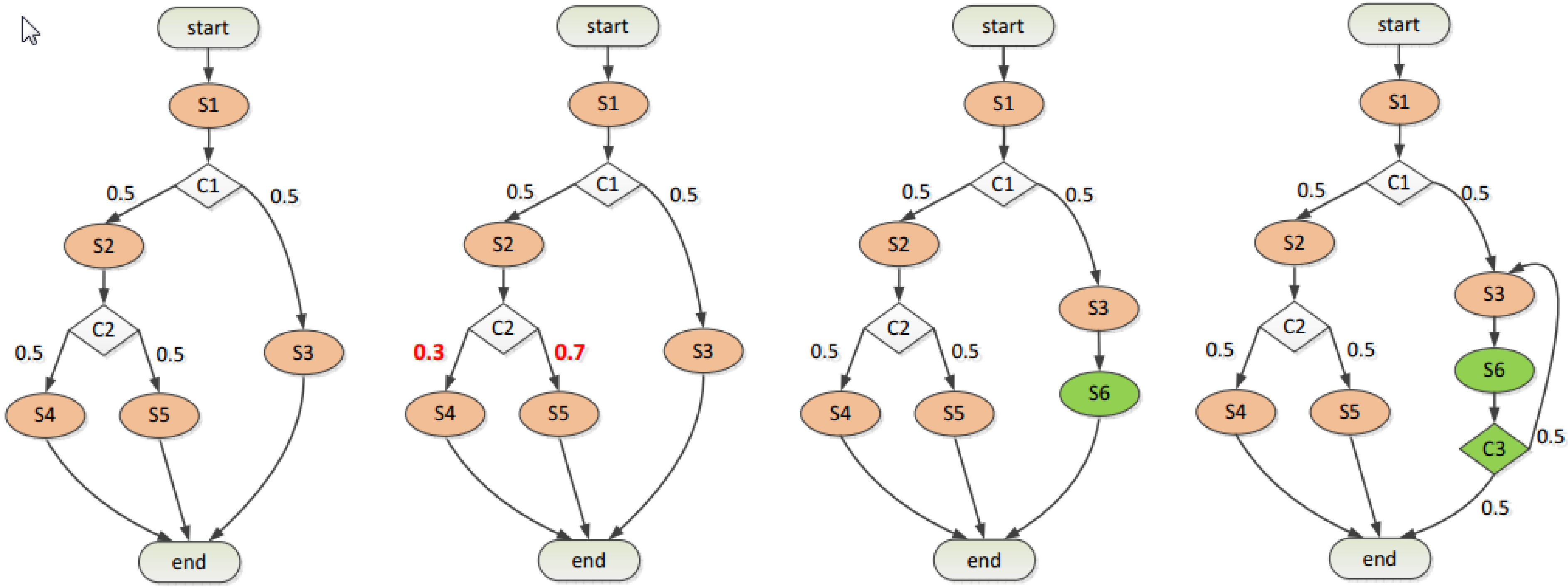
Two Models and Entropy Definition (cont.)

2) Adapted Distance Entropy

$$H_d = \frac{W}{|T|} \times \left(- \sum_{i=1}^{|T|} \frac{w_i}{W} \cdot \log \frac{w_i}{W} \right), \qquad (2)$$

in which, w_i is the average of the distance from T_i to other $(|T| - 1)$ traces. $W = \sum_{i=1}^{|T|} w_i$. T is the execution trace set of a service system.

A running example



(a) System A (b) System B (c) System C (d) System D

Fig. 2. Four example systems for illustrating the dynamic complexity measurement methods

◆ **System Complexity Relation**: D > C > A > B.

A running example(cont.)

TABLE I
THE EXECUTION TRACES OF FOUR SERVICE SYSTEM ($|T| = 20$)

System	Category of Traces	Execution Traces	Occurrence Number
A	C_{A1}	$s_1 \to s_2 \to s_4$	5
	C_{A2}	$s_1 \to s_2 \to s_5$	5
	C_{A3}	$s_1 \to s_3$	10
B	C_{B1}	$s_1 \to s_2 \to s_4$	3
	C_{B2}	$s_1 \to s_2 \to s_5$	7
	C_{B3}	$s_1 \to s_3$	10
C	C_{C1}	$s_1 \to s_2 \to s_4$	5
	C_{C2}	$s_1 \to s_2 \to s_5$	5
	C_{C3}	$s_1 \to s_3 \to s_6$	10
D	C_{D1}	$s_1 \to s_2 \to s_4$	5
	C_{D2}	$s_1 \to s_2 \to s_5$	5
	C_{D3}	$s_1 \to s_3 \to s_6$	5
	C_{D4}	$s_1 \to s_3 \to s_6 \to s_3 \to s_6$	5

A running example(cont.)

TABLE II
THE SERVICE UNIT VECTORS OF FOUR SERVICE SYSTEMS

Sys.	Categ.	Service Unit Vector						Num.	Prob.
		s_1	s_2	s_3	s_4	s_5	s_6		
A	C_{A1}	1	1	0	1	0	0	5	0.25
	C_{A2}	1	1	0	0	1	0	5	0.25
	C_{A3}	1	0	1	0	0	0	10	0.5
B	C_{B1}	1	1	0	1	0	0	3	0.15
	C_{B2}	1	1	0	0	1	0	7	0.35
	C_{B3}	1	0	1	0	0	0	10	0.5
C	C_{C1}	1	1	0	1	0	0	5	0.25
	C_{C2}	1	1	0	0	1	0	5	0.25
	C_{C3}	1	0	1	0	0	1	10	0.5
D	C_{D1}	1	1	0	1	0	0	5	0.25
	C_{D2}	1	1	0	0	1	0	5	0.25
	C_{D3}	1	0	1	0	0	1	10	0.5

A running example(cont.)

TABLE III
THE SERVICE PAIRS OF FOUR SERVICE SYSTEMS

System	Category of Traces	Service Pair						Number	Probability
		(s_1, s_2)	(s_1, s_3)	(s_2, s_4)	(s_2, s_5)	(s_3, s_6)	(s_6, s_3)		
A	C_{A1}	1	0	1	0	0	0	5	0.25
	C_{A2}	1	0	0	1	0	0	5	0.25
	C_{A3}	0	1	0	0	0	0	10	0.5
B	C_{B1}	1	0	1	0	0	0	3	0.15
	C_{B2}	1	0	0	1	0	0	7	0.35
	C_{B3}	0	1	0	0	0	0	10	0.5
C	C_{C1}	1	0	1	0	0	0	5	0.25
	C_{C2}	1	0	0	1	0	0	5	0.25
	C_{C3}	0	1	0	0	1	0	10	0.5
D	C_{D1}	1	0	1	0	0	0	5	0.25
	C_{D2}	1	0	0	1	0	0	5	0.25
	C_{D3}	0	1	0	0	1	0	5	0.25
	C_{D4}	0	1	0	0	1	1	5	0.25

A running example(cont.)

TABLE V
The measure result based on four dynamic complexity metrics

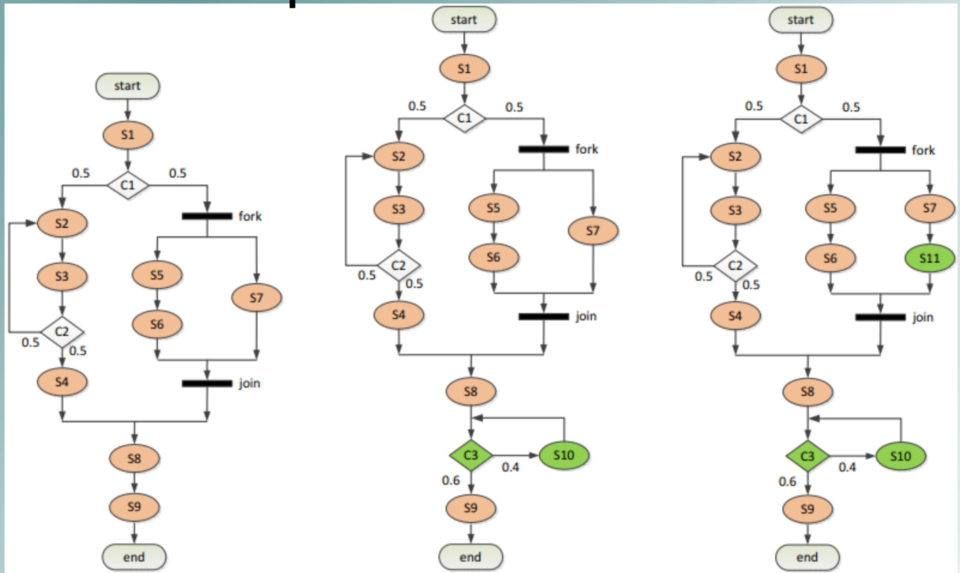
Model	Metric	Service-oriented system			
		A	B	C	D
Service unit vector	$H_s(*, suv)$	1.5	1.44	1.5	1.5
	$H_d(*, suv)$	1.4212	1.3828	1.6055	1.6055
Service pair matrix	$H_s(*, spm)$	1.5	1.44	1.5	2
	$H_d(*, spm)$	1.4212	1.3828	1.6055	1.8628

- Only $\boldsymbol{H_d(*, spm)}$ metric result is consistent with the real dynamic complexity relation of four systems: D > C > A > B.

Experimental Analysis

- Experiment Setup

An online travel service system is used for the simulation analysis. As shown in Figure 3. For each version of the service system, $|T| = 100$ execution traces are simulated and the experiment in each case is repeated 1000 times.



(a) Version One ($VS1$) (b) Version Two ($VS2$) (c) Version Three ($VS3$)

Fig. 3. The business logic of an online travel service system

Experimental Results

- Suggestions on selection measurement method

TABLE VI
THE MEASUREMENT RESULTS OF THE ONLINE TRAVEL SERVICE SYSTEM

Model	Metric	System Version		
		$VS1$	$VS2$	$VS3$
service unit vector	$H_s(*, suv)$	0.9965	1.9518	1.9519
	$H_d(*, suv)$	2.4456	3.0216	3.2128
service pair matrix	$H_s(*, spm)$	2.0817	3.4863	3.6342
	$H_d(*, spm)$	3.7762	4.8434	5.0267

$H_d(*, spm)$ is the best measurement method.

Conclusions

- Main contributions:
  1) Two representation models;
  2) Adapted distance entropy;
  3) Four dynamic complexity metrics.

- According to the experimental analysis, the results show that the above two models and two entropies are all suitable to depict the dynamic complexity of a service system. Among them, the combination of service pair matrix and the adapted distance entropy is the best measurement method.

Thanks for Your Attendance!

Any Question ?

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