Using Structure-Behavior Coalescence Method for Systems Definition 2.0

Hsien-Tzu Wang
Dept. of Information Management
Cheng Shiu University
Kaohsiung, Taiwan, R.O.C.
hwang63@gcloud.csu.edu.tw

Wei-ming Ma
Mathematics and Physics Group of
General Education Center
R.O.C. Air Force Academy
Kaohsiung, Taiwan, R.O.C.
0000-0002-9334-1415

William S. Chao
Dept. of Information Management
National Sun Yat-sen University
Kaohsiung, Taiwan, R.O.C.
aritectchao@gmail.com

Abstract—System definitions are artifacts built by humans to depict what a system is. System definition 1.0 defines a system as a dubiously coalesced whole, embodied in its components. System Definition 1.0 possesses a major flaw that lacks the capability of specifying the coalescence of structure and behavior. The structure-behavior coalescence (SBC) approach supports a graceful way to coalesce structure and behavior. Thus by using SBC, system definition 2.0 shall define a system as a truly coalesced whole, embodied in its assembled components. Since system definition 2.0 specifies the coalescence of system structure and system behavior, it can certainly shape a fully coalesced system.

Keywords—system behavior, system structure, structure-behavior coalescence

I. INTRODUCTION

A system is a set of interconnected or interdependent elements or components that work together to achieve a common purpose or goal. These elements could be physical components, processes, people, or even abstract concepts. Systems can be seen in various domains such as physical systems, biological systems, social systems, and many others [1]-[5].

Because structure and behavior play the dual distinguished parts of a system, coalescing the system structure and system behavior supposedly is the finest method to accomplish a genuinely coalesced system [6]-[7]. If we are not able to coalesce the structure and behavior, then there is no way that we are able to coalesce the whole system. In other words, the structure-behavior coalescence (SBC) method facilitates a truly integrated whole [8]-[12].

The remainder of this paper is arranged as follows. Conventional system definition, failing to coalesce the structure and behavior, is examined in Section II. Section III explores the SBC method for system definition 2.0. A case study is presented in Section IV. Section V discusses the conclusions.

II. LITERATURE REVIEW

In most systems, the structure and behavior are intimately connected. The way components are organized and interact directly impacts how the system behaves. Failing to coalesce these aspects can lead to an incomplete or inaccurate definition of the system.

If we have separate models for structure and behavior that are not properly aligned, it becomes challenging to create a unified, consistent system model. Inconsistencies can lead to gaps in understanding, potentially resulting in an incomplete system definition.

The Structure-Behavior Coalescence approach provides a structured approach to defining complex systems by unifying their structural and behavioral aspects within a single model. This not only enhances the clarity and precision of the system definition but also supports system analysis, communication, and adaptation to changes, ultimately contributing to a more effective systems definition 2.0 process within the context of systems engineering.

III. METHOD OF STRUCTURE-BEHAVIOR COALESCENCE

We elaborate on the SBC method used for System Definition 2.0 in this Section.

A. Handshake Communications

Fig. 1 shows a handshake communication that the caller agent rendezvous with the callee agent.

![Handshake Communications](image)

B. Items of Structure-Behavior Coalescence-PA

In Table I, we can see all possible items that occur in the SBC process algebra.

| Item Set | Item Name | Item Type |
|----------|-----------|-----------|
| G        | g1, g2... | guard conditions |
| D        | d1, d2... | handshake communications |
| C        | c1, c2... | program fragments |
| PX       | px1, px2... | prefixes |
| S        | s1, s2... | states |

C. Prefix of Structure-Behavior Coalescence-PA

Let us see the prefix occurring in the Structure-Behavior Coalescence process algebra here.

**DEFINITION** A prefix $P = (G, D, C, PX)$ contains

- a set $G$ of guards,
• a set \( D \) of handshake communications,
• a set \( C \) of program fragments,
• a relation \( PX \subseteq G \times D \times C \), and \( (g, d, c) \in PX \).

D. Syntax of Structure-Behavior Coalescence-PA

The syntax of SBC-PA is formally specified by the following grammar, as shown in Fig. 2.

\[
\begin{align*}
(1) & \quad s ::= () \\
(2) & \quad s ::= px \bullet s_1 \\
(3) & \quad s ::= (s_1 + s_2) \\
(4) & \quad s ::= (s_1 \parallel s_2) \\
(5) & \quad s ::= \text{loop ITG} \\
(6) & \quad s ::= \text{ref A}
\end{align*}
\]

E. ITG Overview Diagram

The following definition shows how an ITG overview diagram (IOD) is organized.

\[s_{37} \overset{\text{def}}{=} (s_{38} \parallel px_{39} \bullet (\text{ref } s_{39})) \parallel ((\text{ref } s_{26}) + (\text{ref } s_{36}))\]

The corresponding diagram of this ITG overview diagram is shown in Fig. 3.

F. Transitional Semantics of Structure-Behavior Coalescence-PA

An ITG is used to specify the semantics of the Structure-Behavior Coalescence-PA.

DEFINITION An ITG = \((S, (c_0, s_0), PX, ITGR)\) contains
• a non-empty set \( S \) of states with the initial state \( s_0 \in S \),
• a program fragment \( c_0 \in C \),
• a relation \( PX \) of prefixes,
• a relation \( ITGR \subseteq S_1 \times PX \times S_2 \), and \((s_p, px, s_k) \in ITGR\) is denoted by \( s_p \xrightarrow{px} s_k \).

For example, the \( ITGR_{44} = \{(s_{44}, (\text{nil}, d_{44}, \text{nil}), s_{45}), (s_{44}, (\text{nil}, d_{45}, B = B + 50;), s_{46}), (B > 300, d_{46}, \text{nil})\} \) constitutes the ITG \( s_{44} = (S, (B = 600;), s_{44}), PX, ITGR_{44}) \), as shown in Fig. 4.

In the ITG, whenever \( s \xrightarrow{px_1 \ldots px_n} s' \), then \((px_1 \ldots px_n, s')\) is a derivative of \( s \). For the initial state \( s_0 \), if \( s_0 \xrightarrow{px_1 \ldots px_n} s_0 \) does appear, then the ITG is a loop specification of state \( s_0 \). As an example, the \( ITGR_{54} = \{(s_{54}, (\text{d_number} > 0, d_{54}, \text{d_number} = \text{d_number} - 1 ''), s_{55}), (s_{55}, (\text{nil}, d_{55}, \text{nil}), s_{54}), (s_{54}, (\text{d_number} <= 0, d_{56}, \text{nil})\} \) constitutes the ITG \( s_{54} = (S, ((\text{d_number} = 100;), s_{54}), PX, ITGR_{54}) \), as shown in Fig. 5. In \( ITG_{54}, s_{54} \xrightarrow{px_{13} \ldots px_{32}} s_{54} \) does appear for the initial state \( s_{54} \), so \( ITG_{54} \) serves as the loop definition of the state \( s_{54} \), i.e., \( s_{54} = \text{loop } ITG_{54} \).
The complete set of transition rules of the Structure-Behavior Coalescence-PA, is shown in Fig. 6.

IV. CASE STUDY: AUTOMATED TELLER MACHINE

The IOD of the automated teller machine (ATM) with the following definition is shown in Fig. 7.

\[
s_{\text{ATM}} \text{def} (\text{ref } s^{101}) \sqcup (\text{ref } s^{201}) \sqcup (\text{ref } s^{301})
\]

The interaction transition relation ITGR_{201} = \{(s^{201}, (nil, (Operator, refillCash(in cash), :ATM), nil), s^{201})\} constitutes ITG_{201} = (S, (nil, s^{201}), PX, ITGR_{201}). Fig. 9 shows the ITG_{201} which is represented by s^{201}.

The interaction transition relation ITGR_{301} = \{(s^{301}, (nil, (Operator, shutDown, :ATM), nil), s^{301})\} constitutes the ITG_{301} = (S, (nil, s^{301}), PX, ITGR_{301}). Fig. 10 shows the ITG_{301} which is represented by s^{301}.

V. CONCLUSION

Structure-Behavior Coalescence can be used as a methodology within systems engineering to help achieve the definition and representation of complex systems.

In summary, SBC provides a structured approach to defining complex systems by unifying their structural and behavioral aspects within a single model. This not only enhances the clarity and precision of the system definition but also supports system analysis, communication, and adaptation.
to changes, ultimately contributing to a more effective systems
definition 2.0 process within the context of systems
engineering.

REFERENCES

[1] A. Kaposi et al., Systems, Models and Measure, Springer-Verlag
London Limited, 1994.
[2] L. Bertalanffy, General System Theory: Foundations, Development,
Applications. George Braziller Inc., 1969.
[3] L. Skyttner, General Systems Theory: Problems, Perspectives, Practice,
2nd edition, World Scientific Pub Co Inc., 2006.
[4] J. W. Forrester, Principles of Systems, Pegasus Communications, 1968.
[5] W. S. Chao, General Systems Theory 2.0: General Architectural
Theory Using the SBC Architecture, CreateSpace Independent
Publishing, 2014.
[6] D. Dori, Object-Process Analysis: Maintaining the Balance between
System Structure and Behavior, Journal of Logic and Computation 5(2),
pp. 227-249, 1995.
[7] W. Ma and W. S. Chao, Contemporary Concepts, Descriptions and
Language of Systems Using SBC Process Algebra, 13th International
Conference on Information & Communication Technology and System
(ICTS), 2021, pp. 294-300, doi: 10.1109/ICTS52701.2021.9608600.
[8] K.-P. Lin and W. S. Chao, "The Structure-Behavior Coalescence
Approach for Systems Modeling," IEEE Access, Vol. 7, pp. 8609-8620,
2019.
[9] W. Ma and W. S. Chao, Structure-Behavior Coalescence Abstract State
Machine for Metamodel-Based Language in Model-Driven
Engineering, IEEE Systems Journal, vol. 15, no. 3, pp. 4105-4115, Sept.
2021, doi: 10.1109/JSYST.2020.3027195.
[10] Rui-Rui Chen, Chien-Chung Lin, Lin Wang, and William S. Chao,
Software Architecture Design of Animation Studies Platform Using
Structure-Behavior Coalescence Method, Journal of Circuits, Systems
and Computers, Vol. 31, No. 06, 2250103, 2022.
[11] S. Haga, W. M. Ma, and W. S. Chao, “Structure-behavior coalescence
method for formal specification of UML 2.0 sequence diagrams,”
Journal of Computing Science and Engineering, vol. 15, no. 4, pp. 148-
159, 2021.
[12] Steve W. Haga, Wei-Ming Ma, & William S. Chao, Using the
Structure-Behavior Coalescence Method to Formalize the Action Flow
Semantics of UML 2.0 Activity Diagrams. Journal of Computing
Science and Engineering, 17(2), 60-70, 10.5626/JCSE.2023.17.2.60.