

Fig.9 A framework for customization of service processes based on structure evolution

图 9 基于流程结构演化的服务流程定制框架

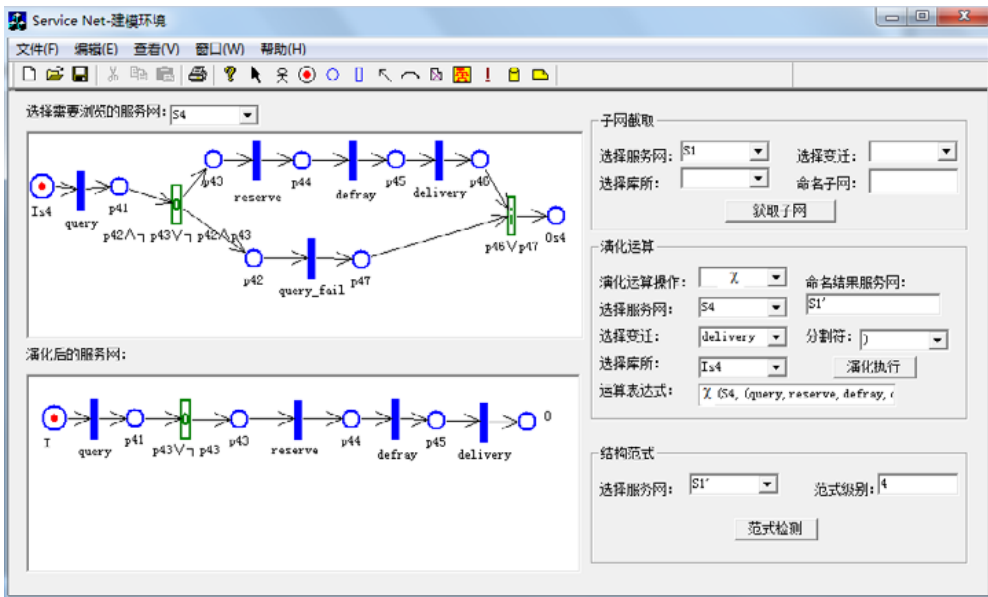


Fig.10 Simulation platform

图 10 仿真验证平台



## 6 结束语

服务流程的结构演化是通过对已有服务流程的分解、截取、链接以及合成等操作组建新服务流程的一种有效方法。相比现有以原子服务作为基本服务组合对象的服务组合方法,通过流程结构演化的方式构建组合服务流程,可以重用已有服务流程资源中的大粒度流程片段,从而有效地降低了服务组合的难度。

文中采用逻辑 Petri 网作为形式化建模工具,通过分析几类不同的演化需求场景,构建了基于逻辑 Petri 网的服务流程结构演化运算,提供了一种在流程模型层面描述流程结构演化的形式化方法,并在前期工作的基础上,探讨了所建立的结构演化运算对流程结构范式的保持问题。本文后续工作主要是进一步归纳和提炼演化场景,完善结构演化运算的功能,并研究所建立结构演化运算的完备性问题,同时,完善仿真验证平台的设计与开发。

### References:

- [1] Puthal D, Sahoo BPS, Mishra S, Swain S. Cloud computing features, issues, and challenges: A big picture. In: Proc. of the Int'l Conf. on Computational Intelligence and Networks. Odisha: IEEE, 2015. 116–123. [doi: 10.1109/CINE.2015.31]
- [2] Wortmann F, Flüchter K. Internet of things. *Business & Information Systems Engineering*, 2015,57(3):221–224. [doi: 10.1007/s12599-015-0383-3]
- [3] Borowik G, Woźniak M, Fornaia A, *et al.* A software architecture assisting workflow executions on cloud resources. *Int'l Journal of Electronics and Telecommunications*, 2015,61(1):17–23. [doi: 10.1515/eletel-2015-0002]
- [4] Patti E, Syrri ALA, Jahn M, Mancarella P, Acquaviva A, Macii E. Distributed software infrastructure for general purpose services in smart grid. *IEEE Trans. on Smart Grid*, 2016,7(2):1156–1163.
- [5] Bertolino A, Blake MB, Mehra P, Mehra P, Mei H, Xie T. Software engineering for Internet computing: Internetwork and beyond. *IEEE Software*, 2015,32(1):35–37.
- [6] Lemos AL, Daniel F, Benatallah B. Web service composition: A survey of techniques and tools. *ACM Computing Surveys*, 2016, 48(3):33–73.
- [7] Wang HY, Li SR. Service substitution method based on composition context. *Journal on Communications*, 2014,35(9):57–66 (in Chinese with English abstract). [doi: 10.3969/j.issn.1000-436x.2014.09.006]
- [8] Liu Y, Zhang YC, Zhang B, Zhang MW, Zhu ZL. Analysis of service replaceability on behavior effect. *Journal of Computer Research and Development*, 2015,47(8):1442–1449 (in Chinese with English abstract).
- [9] Yahyaoui H, Maamar Z, Lim E, Thiran P. Towards a community-based, social network-driven framework for Web services management. *Future Generation Computer Systems*, 2013,29(6):1363–1377. [doi: 10.1016/j.future.2013.02.003]
- [10] Saboohi H, Amini A, Abolhassani H. Failure recovery of composite semantic web services using subgraph replacement. In: Proc. of the 5th Int'l Conf. on Secure Software Integration and Reliability Improvement. Jeju Island, 2011. 182–188.
- [11] Song W, Ma XX, Lv J. Instance migration in dynamic evolution of Web service compositions. *Chinese Journal of Computers*, 2009, 32(9):1816–1831 (in Chinese with English abstract). [doi: 10.3724/sp.j.1016.2009.01816]
- [12] Goswami A, Patel RP. Service migration in cluster based cloud computing environment. In: Proc. of the Int'l Conf. on Information Processing. Maharashtra: IEEE, 2015. 468–471.
- [13] Fokaefs M, Mikhael R, Tsantalis N, Stroulia E. An empirical study on Web service evolution. In: Proc. of the IEEE 18th Int'l Conf. on Web Services. Washington: IEEE, 2011. 49–56.
- [14] Romano D, Pinzger M. Analyzing the evolution of Web services using fine-grained changes. In: Proc. of the IEEE 19th Int'l Conf. on Web Services. Hawaii: IEEE, 2012. 392–399.
- [15] Andrikopoulos V, Benbernou S, Papazoglou MP. On the evolution of services. *IEEE Trans. on Software Engineering*, 2012,38(3): 609–628.
- [16] Wang HM, Shi PC, Ding B, Yin G, Shi DX. Online evolution of software services. *Chinese Journal of Computer*, 2011,34(2): 318–328 (in Chinese with English abstract). [doi: 10.3724/sp.j.1016.2011.00318]
- [17] Seinturier L, Merle P, Rouvov R, Romero D, Schiavoni V, Stefani JB. A component-based middleware platform for reconfigurable service-oriented architectures. *Software: Practice and Experience*, 2012,42(5):559–583.
- [18] Wei L, Li YL, Zhao QY, Shu HP. Dynamic changing model of workflow process based on adaptive component. *Computer Integrated Manufacturing Systems*, 2010,16(12):2603–2610 (in Chinese with English abstract).

- [19] Zeng J, Sun HL, Liu XD, Deng T, Huai JP. Dynamic evolution mechanism for trustworthy software based on service composition. *Ruan Jian Xue Bao/Journal of Software*, 2010,21(2):261–276 (in Chinese with English abstract). <http://www.jos.org.cn/1000-9825/3735.htm> [doi: 10.3724/SP.J.1001.2010.03735]
- [20] Wang S, Huang L, Hsu CH, Yang FC. Collaboration reputation for trustworthy Web service selection in social networks. *Journal of Computer and System Sciences*, 2016,82(1):130–143.
- [21] Song M, Wei ZX, Yin GS. Evolution analysis of data flow oriented internetware service. *Ruan Jian Xue Bao/Journal of Software*, 2013,24(12):2797–2813 (in Chinese with English abstract). <http://www.jos.org.cn/1000-9825/4396.htm> [doi: 10.3724/SP.J.1001.2013.04396]
- [22] Ryu SH, Casati F, Skogsrud H, Benatallah B, Paul RS. Supporting the dynamic evolution of Web service protocols in service-oriented architectures. *ACM Trans. on the Web*, 2008,2(2):1–43.
- [23] He J. Study on the evolution for SaaS service driven by requirement [MS. Thesis]. Kunming: Yunnan University, 2013. 78–89 (in Chinese).
- [24] Deng SG, Huang LT, Tan W, Wu ZH. Top-*k* automatic service composition: A parallel method for large-scale service sets. *IEEE Trans. on Automation Science and Engineering*, 2014,11(3):891–905.
- [25] Hamadi R, Benatallah B. A Petri net-based model for Web service composition. In: *Proc. of the 14th Australasian Database Conf. Adelaide*, 2003. 191–200.
- [26] da Silva AS, Ma H, Zhang M. GraphEvol: A graph evolution technique for Web service composition. In: *Proc. of the Int'l Conf. on Database and Expert Systems Applications. Springer Int'l Publishing*, 2015. 134–142.
- [27] Mohammad AF, Dargham J, Mcheick HT, Noor A. Software evolution as SaaS: Evolution of intelligent design in cloud. *Procedia Computer Science*, 2013,19:486–493.
- [28] Ralph M. Using variability descriptors to describe customizable SaaS application templates. In: *Proc. of the Institute of Architecture of Application Systems*. 2008. 1–27.
- [29] Schumm D, Dentsas D, Hahn M, Karastoyanova D, Leymann F, Sonntag M. Web service composition reuse through shared process fragment libraries. In: *Proc. of the Web Engineering. Berlin, Heidelberg: Springer-Verlag*, 2012. 498–501.
- [30] Van der Aalst WMP. Verification of workflow nets. In: *Proc. of the Int'l Conf. on Application and Theory of Petri Nets. Berlin, Heidelberg: Springer-Verlag*, 1997. 407–426.
- [31] van der Aalst WMP, van Hee KM, ter Hofstede AHM, Sidorova N, Verbeek HMW, Voorhoeve M, Wynn MT. Soundness of workflow nets: Classification, decidability, and analysis. *Formal Aspects of Computing*, 2011,23(3):333–363. [doi: 10.1007/s00165-010-0161-4]
- [32] Liu G, Jiang C. Co-NP-Hardness of the soundness problem for asymmetric-choice workflow nets. *IEEE Trans. on Systems, Man, and Cybernetics: Systems*, 2015,45(8):1201–1204.
- [33] Clempner J. Verifying soundness of business processes: A decision process Petri nets approach. *Expert Systems with Applications*, 2014,41(11):5030–5040.
- [34] Boucheneb H, Barkaoui K. Partial order reduction for checking soundness of time workflow nets. *Information Sciences*, 2014,282: 261–276.
- [35] Sheng QZ, Maamar Z, Yao L, *et al.* Behavior modeling and automated verification of Web services. *Information Sciences*, 2014, 258:416–433.
- [36] Hu Q, Du JW, Du YY. The structure normal form of Web service processes and its testing algorithm. *Chinese Journal of Computers*, 2015,38(1):178–190 (in Chinese with English abstract). [doi: 10.3724/sp.j.1016.2015.00178]
- [37] Quintanilla FG, Cardin O, L'Anton A, et Szabo G, Bourne S. A Petri net-based methodology to increase flexibility in service-oriented holonic manufacturing systems. *Computers in Industry*, 2016,76:53–68.
- [38] Mateescu R, Poizat P, Salaün G. Adaptation of service protocols using process algebra and on-the-fly reduction techniques. *IEEE Trans. on Software Engineering*, 2012,38(4):755–777. [doi: 10.1109/TSE.2011.62]
- [39] Li YX, Yao XF, Xu C, Zhang J, Li B. Cloud manufacturing service composition modeling and Qos evaluation based on process calculus. *Computer Integrated Manufacturing Systems*, 2014,20(3):689–700 (in Chinese with English abstract).
- [40] Wu X, Zhu H. Formalization and analysis of the REST architecture from the process algebra perspective. *Future Generation Computer Systems*, 2016,56:153–168.

- [41] Lei LH, Duan ZH. An extended deterministic fine automata based method for the verification of composite Web service. Ruan Jian Xue Bao/Journal of Software, 2007,18(12):2980–2990 (in Chinese with English abstract). <http://www.jos.org.cn/1000-9825/18/2980.htm> [doi: 10.1360/jos182980]
- [42] Belkhir W, Chevalier Y, Rusinowitch M. Parametrized automata simulation and application to service composition. Journal of Symbolic Computation, 2015,69:40–60. [doi: 10.1016/j.jsc.2014.09.029]
- [43] Hu Q, Du YY, Yu SX. Service net algebra based on logic Petri nets. Information Sciences, 2014,268:271–289.
- [44] Du YY, Qi L, Zhou MC. Analysis and application of logical Petri nets to e-commerce systems. IEEE Trans. on Systems, Man, and Cybernetics: Systems, 2014,44(4):468–481.
- [45] Liu W, Du YY, Zhou MC, Yan C. Transformation of logical workflow nets. IEEE Trans. on Systems, Man, and Cybernetics: Systems, 2014,44(10):1401–1412.

#### 附中文参考文献:

- [7] 王海艳,李思瑞.基于组合上下文的服务替换方法.通信学报,2014,35(9):57–66. [doi: 10.3969/j.issn.1000-436x.2014.09.006]
- [8] 刘莹,张一川,张斌,等.基于行为效果的服务可替换性分析.计算机研究与发展,2015,47(8):1442–1449.
- [11] 宋巍,马晓星,吕建.Web 服务组合动态演化的实例可迁移性.计算机学报,2009,32(9):1816–1831. [doi: 10.3724/sp.j.1016.2009.01816]
- [16] 王怀民,史佩昌,丁博,等.软件服务的在线演化.计算机学报,2011,34(2):318–328. [doi: 10.3724/sp.j.1016.2011.00318]
- [18] 魏乐,李亚玲,赵秋云,等.基于自适应构件的工作流流程动态变更模型.计算机集成制造系统,2010,16(12):2603–2610.
- [19] 曾晋,孙海龙,刘旭东,邓婷,怀进鹏.基于服务组合的可信软件动态演化机制.软件学报,2010,21(2):261–276. <http://www.jos.org.cn/1000-9825/3735.htm> [doi: 10.3724/SP.J.1001.2010.03735]
- [21] 宋敏,韦正现,印桂生.面向数据流的网构软件服务动态演化分析.软件学报,2013,24(12):2797–2813. <http://www.jos.org.cn/1000-9825/4396.htm> [doi: 10.3724/SP.J.1001.2013.04396]
- [23] 何俊.需求驱动的 Saas 服务演化研究[硕士学位论文].昆明:云南大学,2013.78–89.
- [36] 胡强,杜军威,杜玉越.Web 服务流程的结构范式及其判定算法.计算机学报,2015,38(1):178–190. [doi: 10.3724/sp.j.1016.2015.00178]
- [39] 李永湘,姚锡凡,徐川,等.基于扩展进程代数的云制造服务组合建模与 QoS 评价.计算机集成制造系统,2014,20(3):689–700.
- [41] 雷丽晖,段振华.一种基于扩展有限自动机验证组合 Web 服务的方法.软件学报,2007,18(12):2980–2990. <http://www.jos.org.cn/1000-9825/18/2980.htm> [doi: 10.1360/jos182980]



胡强(1980—),男,山东邹城人,博士,讲师,CCF 专业会员,主要研究领域为 Petri 网理论,服务计算,软件形式化分析方法.



杜军威(1974—),男,博士,教授,CCF 专业会员,主要研究领域为软件测试,形式化验证.



任志考(1969—),男,副教授,主要研究领域为软件形式化建模,流程优化.



杜玉越(1960—),男,博士,教授,博士生导师,CCF 高级会员,主要研究领域为 Petri 网理论,形式化方法,人工智能.



赵振(1982—),男,博士,讲师,主要研究领域为智能生产系统,语义网.