软件学报 ISSN 1000-9825, CODEN RUXUEW
Journal of Software,2015,26(2):297−304 [doi: 10.13328/j.cnki.jos.004782]

E-mail: jos@iscas.ac.cn
http://www.jos.org.cn
Tel: +86-10-62562563

多分支单变量循环程序的终止性分析*

李 轶[1], 李传璨[1,2], 吴文渊[1]

[1](自动推理与认知重庆市重点实验室(中国科学院 重庆绿色智能技术研究院),重庆 401120)

[2](重庆邮电大学 计算机科学与技术学院,重庆 400065)

通讯作者: 李轶, E-mail: zm_liyi@163.com

摘 要: 对多分支单变量循环程序的终止性问题进行了研究.证明了在适定的条件下,该类循环程序不可终止性的充分必要条件是迭代映射在循环条件形成的区域中有不动点.特别地,当这类循环程序是多项式循环程序时,在给定条件下,其在实数域上的终止性问题是可判定的.

关键词: 可信计算;多分支循环程序;终止性分析

中图法分类号: TP311

中文引用格式: 李轶,李传璨,吴文渊.多分支单变量循环程序的终止性分析.软件学报,2015,26(2):297−304. http://www.jos.org.cn/1000-9825/4782.htm

英文引用格式: Li Y, Li CC, Wu WY. Termination analysis of multipath loop programs with one variable. Ruan Jian Xue Bao/Journal of Software, 2015,26(2):297−304 (in Chinese). http://www.jos.org.cn/1000-9825/4782.htm

Termination Analysis of Multipath Loop Programs with One Variable

LI Yi[1], LI Chuan-Can[1,2], WU Wen-Yuan[1]

[1](Chongqing Key Laboratory of Automated Reasoning and Cognition (Chongqing Institute of Green and Intelligent Technology, The Chinese Academy of Sciences), Chongqing 401120, China)

[2](College of Computer Science and Technology, Chongqing University of Posts and Telecommunications, Chongqing 400065, China)

Abstract: Termination of multipath loop programs with one variable is analyzed in this paper. It demonstrates that under proper conditions, this kind of loops is non-terminate if and only if there exist fixed points. Especially, if the class of programs are polynomial, then under proper conditions, the termination of the programs is decidable over the reals.

Key words: trusted computing; multipath loop program; termination analysis

随着信息技术的迅猛发展,嵌入式系统在人类生活中发挥着越来越大的作用,而作为嵌入式系统灵魂的嵌入式软件在其中所占有的比重也越来越大.因此,嵌入式软件的可靠性将变得更加重要.诸如航空、航天、军事、交通、医疗等关键应用领域都对嵌入式系统的可靠性和安全性要求非常高,任何错误的发生都可能带来灾难性后果.这些系统被称为攸关安全系统.

嵌入式系统具有 3 个重要属性:可达性、终止性、不变式.可达性是指一个系统能否从一个给定状态到达另一个可接受状态,某些混成系统的可达性被证明是能用计算机代数工具来检验的;不变式则是系统变量在循环迭代时永远保持的特性;而终止性是研究系统中是否会发生死循环.不包括终止性分析的验证被称为程序的部分正确性证明[1],因此,程序的终止性分析是确保程序完全正确性的必要基础.

尽管程序的终止性问题早已被证明是不可判定的[2],但对其进行研究不仅具有理论意义,更具有实际意义.当前,国际上主要通过合成秩函数来进行循环终止性分析.当程序的秩函数被找到时,则表明程序是可终止的.

* 基金项目: 国家自然科学基金(61103110); 重庆市科技攻关项目(cstc2012ggB40004, cstc2013jjys0002)
收稿时间: 2014-07-02; 修改时间: 2014-10-31; 定稿时间: 2014-11-26

[3] Ben-Amram AM, Genaim S. On the linear ranking problem for integer linear-constraint loops. In: Proc. of the 40th Annual ACM SIGPLAN-SIGACT Symp. on Principles of Programming Languages. New York: ACM, 2013. 51–62. [doi: 10.1145/2429069.2429078]

[4] Colón MA, Sipma HB. Practical methods for proving program termination. In: Brinksma E, Larsen KG, eds. Proc. of the Computer Aided Verification. Berlin, Heidelberg: Springer-Verlag, 2002. 227–240. [doi: 10.1007/3-540-45657-0_36]

[5] Colón MA, Sipma HB. Synthesis of linear ranking functions. In: Margaria T, Wang Y, eds. Proc. of the 7th Int'l Conf. on Tools and Algorithms for the Construction and Analysis of Systems. London: Springer-Verlag, 2001. 67–81. [doi: 10.1007/3-540-45319-9_6]

[6] Bagnara R, Mesnard F, Pescetti A, Zaffanella E. A new look at the automatic synthesis of linear ranking functions. Information and Computation, 2012,215:47–67. [doi: 10.1016/j.ic.2012.03.003]

[7] Podelski A, Rybalchenko A. A complete method for the synthesis of linear ranking functions. In: Steffen B, Levi G, eds. Proc. of the Verification, Model Checking, and Abstract Interpretation. Berlin, Heidelberg: Springer-Verlag, 2004. 239–251. [doi: 10.1007/978-3-540-24622-0_20]

[8] Chen YH, Xia BC, Yang L, Zhan NS, Zhou CC. Discovering non-linear ranking functions by solving semi-algebraic systems. In: Jones CB, Liu ZM, Woodcock J, eds. Proc. of the Theoretical Aspects of Computing (ICTAC 2007). Berlin, Heidelberg: Springer-Verlag, 2007. 34–49. [doi: 10.1007/978-3-540-75292-9_3]

[9] Yang L, Zhan NJ, Xia BC, Zhou CC. Program verification by using DISCOVERER. In: Meyer B, Woodcock J, eds. Proc. of the Verified Software: Theories, Tools, Experiments. Berlin, Heidelberg: Springer-Verlag, 2008. 528–538. [doi: 10.1007/978-3-540-69149-5_58]

[10] Cousot P. Proving program invariance and termination by parametric abstraction Langrangian relaxation and semidefinite programming. In: Cousot R, ed. Proc. of the Verification, Model Checking, and Abstract Interpretation. Berlin, Heidelberg: Springer-Verlag, 2005. 1–24. [doi: 10.1007/978-3-540-30579-8_1]

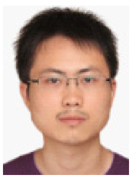
[11] Tiwari A. Termination of linear programs. In: Alur R, Peled DA, eds. Proc. of the Computer Aided Verification. Berlin, Heidelberg: Springer-Verlag, 2004. 70–82. [doi: 10.1007/978-3-540-27813-9_6]

[12] Braverman M. Termination of integer linear programs. In: Ball T, Jones RB, eds. Proc. of the Computer Aided Verification. Berlin, Heidelberg: Springer-Verlag, 2006. 372–385. [doi: 10.1007/11817963_34]

[13] Xia BC, Yang L, Zhan NJ, Zhang ZH. Symbolic decision procedure for termination of linear programs. Formal Aspects of Computing, 2009,23(2):171–190. [doi: 10.1007/s00165-009-0144-5]

[14] Xia BC, Zhang ZH. Termination of linear programs with nonlinear constraints. Journal of Symbolic Computation, 2010,45(11):1234–1249. [doi: 10.1016/j.jsc.2010.06.006]

[15] Bradley A, Manna Z, Sipma H. Termination of polynomial programs. In: Cousot R, ed. Proc. of the Verification, Model Checking, and Abstract Interpretation. Berlin, Heidelberg: Springer-Verlag, 2005. 113–129. [doi: 10.1007/978-3-540-30579-8_8]



李轶(1980－),男,重庆人,博士,副研究员,主要研究领域为程序验证,符号计算.

吴文渊(1976－),男,博士,副研究员,主要研究领域为同伦计算.

李传璨(1989－),男,硕士生,主要研究领域为程序验证.