Towards remote monitoring and reconfiguration of FPGA-based controllers using IOPT-Tools

Gabriel Alves*, Filipe Moutinho*†, Rogerio Campos-Rebelo*†‡, and Luis Gomes*†
*NOVA University Lisbon, NOVA School of Science and Technology, Monte de Caparica, Portugal
†UNINOVA, Center of Technology and Systems, Monte de Caparica, Portugal
‡Polytechnic Institute of Beja, School of Technology and Management, Beja, Portugal
gfp.alves@campus.fct.unl.pt, fcm@fct.unl.pt, rcr@uninova.pt, lugo@fct.unl.pt

***Abstract*—IOPT-Tools is a tool chain framework that supports controllers specification through Petri net models, models validation, and automatic generation of C and VHDL (VHSIC Hardware Description Language) code. Additionally, this framework supports the remote control and monitoring of embedded controllers that were implemented using the automatically generated C code. This paper presents an ongoing work where IOPT-Tools will be extended to support the remote control and monitoring of FPGA (Field Programmable Gate Array) based controllers. Additionally, the IOPT-Tools will be also extended to support the remote reconfiguration of FPGA-based controllers, enabling their adaptation to new application requirements.**

I. Introduction

The world of digital controllers is evolving, and the complex static controllers are no longer meeting all the challenges of the scientific and industry world. The future of the digital controller, namely in the Industry4.0 [1], is the remote monitoring and adaptation of the controller in real time, to the new application requirements. Digital controllers are often implemented in Field Programmable Gate Arrays (FPGAs), which are reconfigurable devices.

There are a high number of papers, presenting works, were FPGAs can be remotely reconfigured, controlled, and monitored, such as in remote laboratories [2]–[4], which often receive as input Bitstream files and HDL (Hardware Description Language) files.

In the ongoing work, presented in this paper, the IOPT-Tools framework [5] will be extended to support, remote monitoring and reconfiguration of FPGA-based controllers. The novelty of the proposed work, is in the use of model-driven development tools, which receive as input platform independent Petri net models [6]. These models can be validated using model-checking tools [7] and automatically translated into C code, to support microcontroller-based implementations [8], and into VHDL (VHSIC Hardware Description Language) code, to support FPGA-based implementations [9]. Currently the IOPT-Tools already support the remote control and monitoring of controllers running in microcontroller-based platforms, such as Arduino or Raspberry Pi [10].

This paper has the following structure. In the next section is briefly described the proposed reconfigurable computing platform, that will be supported by the extended IOPT-Tools. Then the benefits and limitations of the proposed platform are discussed. Finally the conclusions will be presented.

II. Proposed reconfigurable computing platform

The proposed reconfigurable computing platform is presented in Fig. 1. It is represented by the dashed rectangle, which interacts with external systems and with the systems under control. The external system are able to send to the proposed platform:

- a Petri net model (a PMNL file [11]) with the controller behavior;
- commands, such as ”program”, ”run”, and ”stop” the controller; and
- data to force the controllers IOs (inputs and outputs).

Additionally, the external system receives the current controller state and IO values, enabling its monitoring. The controlled system, will react to controller outputs and provide data about it.

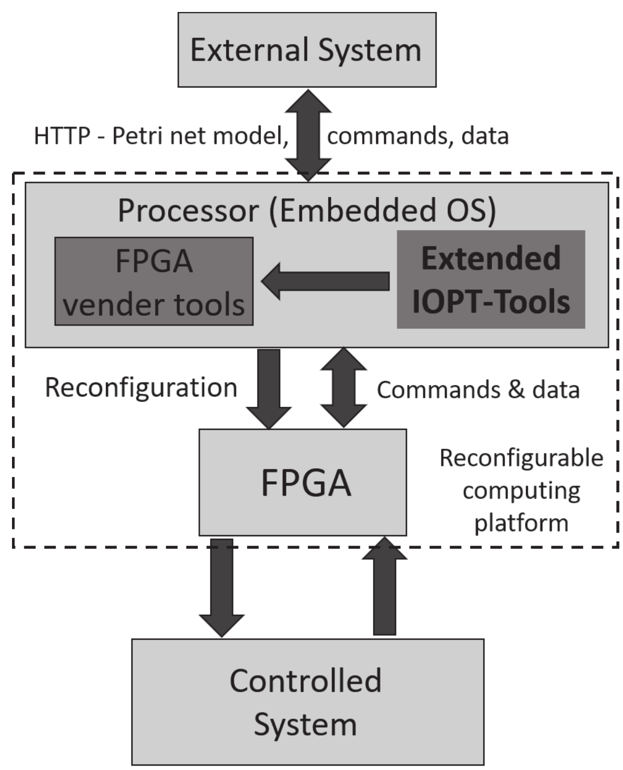

Fig. 1. Proposed reconfigurable computing platform

The supported Petri net formalism is the Input-Output Place-Transition nets (IOPT-nets) [6], which is a Petri net class proposed for automation and embedded systems. These models can be edited in the IOPT-Tools Web-based editor [12], available online at *http://gres.uninova.pt/IOPT-Tools/*. For this step, the developer can use the functionalities of IOPT-Tools to verify and simulate the behavior of the controller.

To implement the controller, the external system must send the created Petri net file with the corresponding command. The reconfigurable computing platform, which will be running the extended version of the IOPT-Tools, should able to support:

- the model validation using the IOPT-model checking tool, which may generate the space state of the controller and verify that the behavior of the controller match with the description of the intended behavior (for example, to check for deadlocks); and
- the automatic translation of the Petri net model into VHDL code.

The extended IOPT-tools computer will be also responsible to check if it is possible to run the controller. Given that, it should be possible to run multiple controllers on a single platform, it is required to check, for instance if they do not control the same outputs. If possible, the automatic VHDL code generator from the IOPT-Tools will generate the corresponding files.

Finally, the FPGA's manufacturer tools, will be invoked by the extended IOPT-tools, to implement the controller(s) in the FPGA. After synthesis, implement design, and Bitstream file generation, the FPGA will be reconfigured.

After the implementation, the proposed platform will support, in real-time, the remote control and monitoring of the FPGA-based controller. For this purpose, the FPGAs will communicate the current state and IOs, whereas, the platform will be able to force the controller inputs.

III. Benefits and Limitations

There are several advantages of using such reconfigurable computing platform. The use of platform independent models, which can be translated into heterogeneous programming and description languages, support heterogeneous implementations and future updates. The possibility to remotely develop, monitor and update the controller, should reduce costs and make it suited for the Industry4.0. The builtin verification and automatic code generation tools may reduce the development errors, making them suited for safety-critical systems.

It is important to discuss also some limitations of the proposed platform. The possibility of running multiple controllers in a single FPGA, may limit controllers update or force other controllers to reset. Given that IOPT Petri nets are not suited to specify all type of systems, they may limit the platform use. Finally, the communications should be secure prevent attacks.

IV. Conclusion

In this paper was proposed and analysed a platform to support FPGA-based controller with remote operation capabilities. At this stage of the work, several tests were successful performed, using a Xilinx's FPGA and the Vivado Design Suite. Several projects were created and synthesized, the designs were implement and the Bitstream files generated, and finally, the FPGAs reconfigured.

Acknowledgment

This work was partially financed by Portuguese Agency "Fundação para a Ciência e a Tecnologia" (FCT), in the framework of project UID/EEA/00066/2019.

The authors would like to thank the multiple people that contributed to the development of IOPT-Tools, and also thank REC'2020 organising committee for the opportunity to expose and debate this idea.

References

[1] E. Hozdić, "Smart factory for industry 4.0: A review," *International Journal of Modern Manufacturing Technologies*, vol. 7, pp. 28–35, 01 2015.

[2] L. Gomes and S. Bogosyan, "Current trends in remote laboratories," *IEEE Transactions on Industrial Electronics*, vol. 56, no. 12, pp. 4744–4756, Dec 2009.

[3] J. Borko, G. Dulnik, A. Grzelka, A. Łuczak, and A. Paszkowski, "A remote programming module of fpga boards," in *Measurement Automation Monitoring*, vol. 61, no. 07, July 2015.

[4] N. Fujii and N. Koike, "Iot remote group experiments in the cyber laboratory: A fpga-based remote laboratory in the hybrid cloud," in *2017 International Conference on Cyberworlds (CW)*, Sep. 2017, pp. 162–165.

[5] F. Pereira, F. Moutinho, and L. Gomes, "IOPT-tools - Towards cloud design automation of digital controllers with Petri nets," in *2014 International Conference on Mechatronics and Control (ICMC)*, July 2014, pp. 2414–2419.

[6] L. Gomes, F. Moutinho, F. Pereira, J. Ribeiro, A. Costa, and J. P. Barros, "Extending input-output place-transition Petri nets for distributed controller systems development," in *2014 International Conference on Mechatronics and Control (ICMC)*, July 2014, pp. 1099–1104.

[7] F. Pereira, F. Moutinho, and L. Gomes, "Model-checking framework for embedded systems controllers development using IOPT Petri nets," in *2012 IEEE International Symposium on Industrial Electronics*, May 2012, pp. 1399–1404.

[8] R. Campos-Rebelo, F. Pereira, F. Moutinho, and L. Gomes, "From IOPT Petri nets to C: An automatic code generator tool," in *2011 9th IEEE International Conf. on Industrial Informatics*, July 2011, pp. 390–395.

[9] F. Pereira and L. Gomes, "Automatic synthesis of VHDL Hardware Components from IOPT Petri Net models." Vienna, Austria: IECON'2013 – The 39th Annual Conference of the IEEE Industrial Electronics Society, 2013.

[10] F. Pereira, A. Melo, and L. Gomes, "Remote operation of embedded controllers designed using IOPT Petri-nets," in *2015 IEEE 13th International Conference on Industrial Informatics (INDIN)*, July 2015, pp. 572–579.

[11] M. Weber and E. Kindler, *The Petri Net Markup Language*. Berlin, Heidelberg: Springer Berlin Heidelberg, 2003, pp. 124–144. [Online]. Available: https://doi.org/10.1007/978-3-540-40022-6_7

[12] F. Pereira, F. Moutinho, J. Ribeiro, and L. Gomes, "Web based IOPT Petri net Editor with an extensible plugin architecture to support generic net operations," in *IECON 2012 - 38th Annual Conference on IEEE Industrial Electronics Society*, Oct 2012, pp. 6151–6156.