Report of PFE

Validation and Development of PLC Design Tool Based on Modeling and Prolog Logic Reasoning

by

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Abstract

This report chronicles the author's 22-week internship experience, dedicated to exploring the domain of "Modeling and Reasoning for PLC Design Tools". This report addresses the need for agile manufacturing systems that adapt to changing demands. The research explores a new approach to PLC programming, emphasizing agility and reusability, aligned with Industry 4.0 goals. The research is rooted in harnessing the potential of the IEC 61499 standard's structured representations for defining system components. This approach is bolstered by the integration of ontology, RDF, Prolog, and rule-based reasoning, enhancing information management, integration, and decision-making. The application of these innovative technologies amplifies the agility and responsiveness of PLC development in Industry 4.0.

The report outlines the internship's objectives, methods, and achievements. It initiates with a comprehensive analysis of the IEC 61499 standard, unveiling its untapped potential. Subsequently, the creation and description of an object-oriented model, inspired by this standard, are elaborated upon. The development of a GUI-based automation system description model is presented, with the utilization of engineering design patterns to enhance maintainability. In conclusion, this paper highlights not only the technical outcomes but also the personal growth achieved during the internship. It underscores the vital role of understanding business requirements, effective communication, and the development of soft skills in the realm of software engineering. The immersive exposure to an authentic industry environment provides valuable insights and cultivates a deeper understanding of innovative development strategies. This research signifies a stepping stone toward more advanced and agile PLC development, while also illuminating the path for future exploration and improvements.

Keywords: Industry 4.0, IEC 61499, Object-Oriented, RDF, Engineering Pattern

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in Nanjing, China

Abbreviations and conventions

IEC	International Electro-technical Commission
XML	Extensible Markup Language
RDF	Resource Description Framework
PLC	Programmable Logic Controller
OO	Object Oriented
UML	Unified Modeling Language
FB	Function Block
OWL	Web Ontology Language
GUI	Graphical User Interface
IO	Input - Output
UUID	Universal Unique Identifier
TDD	Test Driven Development

Bibliography

[1] R. W. Lewis, “Modeling control systems using IEC 61499”, in *Control Engineering Series No. 59*, ISBN: 978-0-85296-796-6.

[2] T. Terzimehic, M. Wenger, A. Zoitl, A. Bayha, K. Becker, T. Müller and H. Schauerte, “Towards an Industry 4.0 Compliant Control Software Architecture Using IEC 61499 & OPC UA”, in *2017 22nd IEEE International Conference on Emerging Technologies and Factory Automation (ETFA)*, Limassol, Cyprus, 2017, pp. 1-4, DOI: 10.1109/ETFA.2017.8247718.

[3] International Electrotechnical Commission (2003) International Standard IEC 61131-3: Programmable Controllers - *Part 3: Programming Languages*.

[4] L. H. Yoong, P. S. Roop, Z. E. Bhatti, M. M. Y. Kuo, “Model-Driven Design Using IEC 61499 - A Synchronous Approach for Embedded and Automation Systems”, in *Springer International Publishing Switzerland 2015*, ISBN: 978-3-319-10521-5, DOI: 10.1007/978-3-319-10521-5

[5] Eclipse 4diac™: IEC 61499 Open-Source PLC Framework for Industrial Automation & Control. https://eclipse.dev/4diac/. Accessed 20 Aug 2023.

[6] G. Antoniou, F. Harmelen, A Semantic Web primer - 2nd ed., in *Massachusetts Institute of Technology 2008*, ISBN: 978-0-262-01242-3

[7] F. Manola, E. Miller, B. McBride. RDF primer, in *W3C recommandation*, 2004, 10(1-107) : 6.

[8] J. Wielemaker, Logic programming for knowledge-intensive interactive applications, in *SIKS Dissertation Series No. 2009-10*

[9] SWI-Prolog: https://www.swi-prolog.org. Accessed 20 Aug 2023.

[10] D. Janzen, H. Saiedian, Test-driven development concepts, taxonomy, and future direction[J], in *Computer, 2005, 38(9): 43-50*.

[11] Mock in Python: https://docs.python.org/3/library/unittest.mock.html. Accessed 20 Aug 2023.

Appendix A: A simplified RDF example

A simplified and abstracted RDF representation corresponding to *Figure 3.3.2* in *Chapter 3.2*, with sensitive information removed:

```
@prefix ComponentNS: <http://mnf.org/autoplc/types/Components/> .
@prefix ContainerNS: <http://mnf.org/autoplc/types/Containers/> .
@prefix ElectricalQtyNS: <http://mnf.org/autoplc/types/ElectricalQties/> .
@prefix InputNS: <http://mnf.org/autoplc/types/Inputs/> .
@prefix OutputNS: <http://mnf.org/autoplc/types/Outputs/> .
@prefix PartNS: <http://mnf.org/autoplc/types/Parts/> .
@prefix PhysicalQtyNS: <http://mnf.org/autoplc/types/PhysicalQties/> .
@prefix QtyUnitNS: <http://mnf.org/autoplc/types/QtyUnits/> .
@prefix mnf: <http://mnf.org/autoplc/types/> .
@prefix ns1: <http://mnf.org/autoplc/properties/> .
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .

mnf:Component a rdfs:Class .
mnf:Container a rdfs:Class .
mnf:ElectricalQty a rdfs:Class .
mnf:Input a rdfs:Class .
mnf:Output a rdfs:Class .
mnf:Part a rdfs:Class .
mnf:PhysicalQty a rdfs:Class .
mnf:QtyUnit a rdfs:Class .
ns1:hasChild a rdf:Property .
ns1:hasInput a rdf:Property .
ns1:hasLabel a rdf:Property .
ns1:hasName a rdf:Property .
ns1:hasOutput a rdf:Property .
ns1:hasQty a rdf:Property .
ns1:hasTag a rdf:Property .
ns1:hasUnit a rdf:Property .

ContainerNS:3980a579-1d42-48fc-bf7e-4174a53424d2 a mnf:Container ;
    ns1:hasChild ComponentNS:c96f7b78-2bab-43ca-829a-0cdbbaa716b0,
        ContainerNS:14b68df7-7ece-4913-9d2c-e5400ca25b24,
        ContainerNS:ed679a34-0269-4064-9289-16b7f75d785f,
        PartNS:2b0ae62b-e1d7-487d-b993-156fe1be1dbe ;
    ns1:hasName "system" .
```

```
ComponentNS:c96f7b78-2bab-43ca-829a-0cdbbaa716b0 a mnf:Component ;
    ns1:hasName "component1" .

ComponentNS:dae98208-b647-4475-99d6-3f5aa447afe8 a mnf:Component ;
    ns1:hasChild PartNS:484f53b8-c0c7-463a-b9c2-98b5c049f27f,
        PartNS:9a3d0d2e-7ab8-4ea0-bf18-aa7650e1c6df,
        PartNS:aa1f8839-07ad-4a12-8b45-baba6fd56079,
        PartNS:e3e4d15c-5962-4558-b165-bb5e1d3e753f ;
    ns1:hasInput InputNS:580d8b5d-f276-48b9-868b-056abfed91f6,
        InputNS:ba1d14c9-6f4c-4d43-a40e-8d668cfb3e66,
        InputNS:c6c47614-fd37-47a4-a1c3-31bf9f985088,
        InputNS:dc2d5ab7-9842-4bfd-a1f6-cd4b1b93c8c5 ;
    ns1:hasName "test_component_1_1" ;
    ns1:hasOutput OutputNS:227f2596-9843-41c3-be65-5af3ef50ccdf,
        OutputNS:286eee3b-f390-4ee9-9b3d-16ec093c61ab,
        OutputNS:6f18256a-2462-49b0-8aef-02a015fa5c9d .

ComponentNS:dd228c74-2336-4a92-b590-4022f24583c0 a mnf:Component ;
    ns1:hasChild ComponentNS:dae98208-b647-4475-99d6-3f5aa447afe8,
        PartNS:142279b4-ece0-4cf6-b18c-fe0e411ff00f ;
    ns1:hasInput InputNS:96b6a9de-ea19-4ba1-a78c-be3cc12e8340 ;
    ns1:hasName "test_component_1" ;
    ns1:hasOutput OutputNS:e8d2fbb5-1f66-4c51-9552-91d51f7a481f .

ContainerNS:14b68df7-7ece-4913-9d2c-e5400ca25b24 a mnf:Container ;
    ns1:hasChild ComponentNS:dd228c74-2336-4a92-b590-4022f24583c0 ;
    ns1:hasName "test_container1" .

ContainerNS:ed679a34-0269-4064-9289-16b7f75d785f a mnf:Container ;
    ns1:hasName "test_container2" .

ElectricalQtyNS:49902bc4-be60-45a9-b4b4-860177b5005e a mnf:ElectricalQty ;
    ns1:hasName "电流(Electric Current)" ;
    ns1:hasUnit QtyUnitNS:03131dd4-1590-4c6e-94e3-0636ed6f6a57 .

ElectricalQtyNS:bd081ed3-ff9b-4e46-b44a-7cec71c66231 a mnf:ElectricalQty ;
    ns1:hasName "电压(Voltage)" ;
    ns1:hasUnit QtyUnitNS:231a712f-199b-44dd-9321-7a3784a4bf90 .

InputNS:580d8b5d-f276-48b9-868b-056abfed91f6 a mnf:Input ;
    ns1:hasName "test_input3" ;
    ns1:hasQty ElectricalQtyNS:bd081ed3-ff9b-4e46-b44a-7cec71c66231 .

InputNS:59dd162c-aca2-4f03-910d-a8ecd8e20cc6 a mnf:Input ;
    ns1:hasName "in_phy_2" ;
    ns1:hasQty PhysicalQtyNS:9eab9c21-70da-4981-aa41-d2f63263c970 .
```

```
InputNS:61a0f7f8-b0fc-465b-aa91-55821f9c74e0 a mnf:Input ;
    ns1:hasName "in_elec_1" ;
    ns1:hasQty ElectricalQtyNS:49902bc4-be60-45a9-b4b4-860177b5005e .

InputNS:96b6a9de-ea19-4ba1-a78c-be3cc12e8340 a mnf:Input ;
    ns1:hasName "test_in_phy" ;
    ns1:hasQty PhysicalQtyNS:1fa59ded-ff5d-4757-92aa-3b0da7564f51 .

InputNS:ba1d14c9-6f4c-4d43-a40e-8d668cfb3e66 a mnf:Input ;
    ns1:hasName "test_input_signal" .

InputNS:bddeb9b3-c9bc-47ae-9d15-87bb07e9a477 a mnf:Input ;
    ns1:hasName "in_phy_1" ;
    ns1:hasQty PhysicalQtyNS:9eab9c21-70da-4981-aa41-d2f63263c970 .

InputNS:c6c47614-fd37-47a4-a1c3-31bf9f985088 a mnf:Input ;
    ns1:hasName "test_input2" ;
    ns1:hasQty PhysicalQtyNS:5eedd355-b406-4d5e-9021-1ae1e6cce432 .

InputNS:dc2d5ab7-9842-4bfd-a1f6-cd4b1b93c8c5 a mnf:Input ;
    ns1:hasName "test_input1" ;
    ns1:hasQty PhysicalQtyNS:1fa59ded-ff5d-4757-92aa-3b0da7564f51 .

OutputNS:07ebe0e3-341c-4429-8d94-57107ad29ef5 a mnf:Output ;
    ns1:hasName "out_elec_1" ;
    ns1:hasQty ElectricalQtyNS:6d05f52c-5768-4f92-88b3-5666df616c53 .

OutputNS:227f2596-9843-41c3-be65-5af3ef50ccdf a mnf:Output ;
    ns1:hasName "test_output1" ;
    ns1:hasQty PhysicalQtyNS:9eab9c21-70da-4981-aa41-d2f63263c970 .

OutputNS:286eee3b-f390-4ee9-9b3d-16ec093c61ab a mnf:Output ;
    ns1:hasName "test_output_signal" .

OutputNS:4218f41a-281d-4376-9682-f6ba5767a446 a mnf:Output ;
    ns1:hasName "out_phy_1" ;
    ns1:hasQty PhysicalQtyNS:9eab9c21-70da-4981-aa41-d2f63263c970 .

OutputNS:6f18256a-2462-49b0-8aef-02a015fa5c9d a mnf:Output ;
    ns1:hasName "test_output2" ;
    ns1:hasQty ElectricalQtyNS:6d05f52c-5768-4f92-88b3-5666df616c53 .
```

```
OutputNS:e8d2fbb5-1f66-4c51-9552-91d51f7a481f a mnf:Output ;
    ns1:hasName "test_out_phy" ;
    ns1:hasQty PhysicalQtyNS:1fa59ded-ff5d-4757-92aa-3b0da7564f51 .

PartNS:142279b4-ece0-4cf6-b18c-fe0e411ff00f a mnf:Part ;
    ns1:hasInput InputNS:59dd162c-aca2-4f03-910d-a8ecd8e20cc6,
        InputNS:61a0f7f8-b0fc-465b-aa91-55821f9c74e0,
        InputNS:bddeb9b3-c9bc-47ae-9d15-87bb07e9a477 ;
    ns1:hasName "test_part_1_1" ;
    ns1:hasOutput OutputNS:07ebe0e3-341c-4429-8d94-57107ad29ef5,
        OutputNS:4218f41a-281d-4376-9682-f6ba5767a446 .

PartNS:2b0ae62b-e1d7-487d-b993-156fe1be1dbe a mnf:Part ;
    ns1:hasName "part1" .

PartNS:484f53b8-c0c7-463a-b9c2-98b5c049f27f a mnf:Part ;
    ns1:hasName "test_part_1_1_1" .

PartNS:9a3d0d2e-7ab8-4ea0-bf18-aa7650e1c6df a mnf:Part ;
    ns1:hasName "test_part_1_1_4" .

PartNS:aa1f8839-07ad-4a12-8b45-baba6fd56079 a mnf:Part ;
    ns1:hasName "test_part_1_1_3" .

PartNS:e3e4d15c-5962-4558-b165-bb5e1d3e753f a mnf:Part ;
    ns1:hasName "test_part_1_1_2" .

PhysicalQtyNS:5eedd355-b406-4d5e-9021-1ae1e6cce432 a mnf:PhysicalQty ;
    ns1:hasName "温度(Temperature)" ;
    ns1:hasUnit QtyUnitNS:1bc998b9-fca7-413f-ab89-2ae80dd0c1cc .

QtyUnitNS:03131dd4-1590-4c6e-94e3-0636ed6f6a57 a mnf:QtyUnit ;
    ns1:hasLabel "安培" ;
    ns1:hasName "A" .

QtyUnitNS:03f840db-4522-420d-a8a8-727203aa526e a mnf:QtyUnit ;
    ns1:hasLabel "转每秒(Revolution Per Second)" ;
    ns1:hasName "r/s" .

QtyUnitNS:1bc998b9-fca7-413f-ab89-2ae80dd0c1cc a mnf:QtyUnit ;
    ns1:hasLabel "摄氏温度" ;
    ns1:hasName "°C" .
```

```
QtyUnitNS:231a712f-199b-44dd-9321-7a3784a4bf90 a mnf:QtyUnit ;
    ns1:hasLabel "伏特" ;
    ns1:hasName "V" .

QtyUnitNS:4acb3c09-4e84-4408-a647-16ef3dc35082 a mnf:QtyUnit ;
    ns1:hasLabel "瓦特" ;
    ns1:hasName "W" .

QtyUnitNS:9f9a69f1-4d2c-4971-b0de-e6f8a74f994e a mnf:QtyUnit ;
    ns1:hasLabel "牛顿" ;
    ns1:hasName "N" .

ElectricalQtyNS:6d05f52c-5768-4f92-88b3-5666df616c53 a mnf:ElectricalQty ;
    ns1:hasName "功率(Power)" ;
    ns1:hasUnit QtyUnitNS:4acb3c09-4e84-4408-a647-16ef3dc35082 .

PhysicalQtyNS:1fa59ded-ff5d-4757-92aa-3b0da7564f51 a mnf:PhysicalQty ;
    ns1:hasName "转速(Rotational Speed)" ;
    ns1:hasUnit QtyUnitNS:03f840db-4522-420d-a8a8-727203aa526e .

PhysicalQtyNS:9eab9c21-70da-4981-aa41-d2f63263c970 a mnf:PhysicalQty ;
    ns1:hasName "压力(Stress)" ;
    ns1:hasUnit QtyUnitNS:9f9a69f1-4d2c-4971-b0de-e6f8a74f994e .
```