Eine Open Source 3-D Visualisierung für das RAMI Industrie 4.0 Referenzmodell

An Open Source 3D Visualization for the RAMI 4.0 Reference Model

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Kurzfassung

Innerhalb dieses Beitrags wird eine Open Source Visualisierung für das Referenzmodell RAMI 4.0 (Referenzarchitekturmodell Industrie 4.0) vorgestellt, welche auf Basis einer bisherigen Entwicklung im Umfeld des Smart Grids und des dazugehörigen SGAM (Smart Grid Architecture Model) entstanden ist. Diese XML-basierte Visualisierung ermöglicht es, als browserbasiertes Werkzeug unter zuhilfenahme verschiedener Eingabeformate wie XML, CSV oder Microsoft Excel respektive Open Office Industrie 4.0-basierende Modellierungen zu laden, navigieren, manipulieren und Metadaten zu den dargestellten Architekturmodellen anzuzeigen sowie externe Links aufzurufen. Es geht dabei über die bisher verfügbaren reinen Microsoft Visio oder Microsoft Powerpoint Shapesets, wie sie etwa im SGAM Umfeld als State-of-the-Art gelten können, hinaus und kann als Werkzeug zur Diskussion in Projektsitzungen oder zur Dokumentation von Lösungen genutzt werden. Zusätzlich wird auch eine Visualisierung für das so genannte ju-RAMI als Ausblick geboten.

Abstract

Within this contribution, we briefly present our developed open source browser-based visualization for the RAMI 4.0 reference model, which is based on out previous developments for the SGAM – Smart Grid Architecture Model in the context of smart grid projects. Based on a client-server browser-based system, an upload for Industrie 4.0 models and examples serialized in Comma Separated Values, XML or Microsoft Excel is provided to visualize the corresponding Industrie 4.0 models. Afterwards, those models can be navigated, manipulated and corresponding meta-data can be visualized using on mouse-over functions. The tool extends the existing Microsoft PowerPoint or Visio shapesets and can be used for either discussion in meetings about the different components of an Industrie 4.0 model or as a documentation tool since graphics exporting functions are provided. In addition to the basic RAMI 4.0 model, extensions to visualize the ju-RAMI are provided.

1 From SGAM to RAMI 4.0 – an Evolution

The generic Smart Grid Architecture Model SGAM can act as a reference designation system in order to describe smart grid (technical) use cases as well as business cases for requirements engineering purposes. After having been applied successfully in the EU M/490 mandate to CEN, CENELEC and ETSI as well as to various FP7 projects, first adaptations of the model in other domains and scopes have been tried out, see [1]. In this overview report contribution, we conduct a brief survey about these adapted models and outline their core aspects from the modeling point of view.

1.1 The SGAM – Smart Grid Architecture Model

The SGAM and its methodology is intended to present the design and technologies of smart grid use cases in an both architectural and technology-neutral manner [14]. In respect to the present scope of the EU M/490 task the SGAM allows for the validation of smart grid use cases and their support by standards.

The SGAM consists of five consistent layers representing use cases, information models, communication protocols and components. Each layer covers the smart grid plane, which is spanned by smart grid domains and levels of scope. The intention of the reference designation model is to allow the presentation of the current state of implementations in the electrical grid, but furthermore to present the evolution to future smart grid scenarios by supporting the principles of extensibility, scalability, upgradability in its core.

The domains modeled in the SGAM reference designation system take into account mainly the energy conversion chain and include: generation (both conventional and renewable bulk generation capacities), transmission (infrastructure and organization for the transport of electricity across long distances), distribution (infrastructure and organization for the distribution of electricity to the customers both industry and private households), DERs (distributed energy resources connected to the distribution grid, directly to the grid or via PCC) and customer premises (both end users and producers of electricity; including industrial, commercial, and home facilities as well as generation in form of, e.g., PV conversion, electric vehicles storage, batteries, as well as micro turbines) [2].

The hierarchy of power system management from the automation as well as utility organizational level perspective is reflected within the SGAM by the definition of the following zones: process (physical, chemical or spatial transformations of energy and the physical equipment directly involved), field (equipment to protect, control and monitor the process of the power system), station (areal aggregation level for field level), operation (power system control operation in the respective domain), enterprise (commercial and organizational processes, services and infrastructures for enterprises), and market (market operations possible along the energy conversion chain).

Finally, as it constitutes a major requirement towards distributed systems, the SGAM defines so called Interoperability Layers based on the GWAC (GridWise Architecture Council) IOP stack [2].

These cover planes to model and allocate entities ranging from business objectives to physical components to express the respective architectural viewpoint from the GWAC stack. As proposed by TOGAF (The Open Group Architecture Framework), interrelations between concepts from different layers shall ensure traceability between documented architecture properties.
One important aspect to take into account when extending the SGAM to different domains is the original scope of the SGAM model. Based on the work from the EU M/490 mandate, the original purpose was modeling the landscape of existing CEN, CENELEC and ETSI (as well as their international mirrors) standards in order to find gaps for needed future smart grids standards and show relations between existing work items and working groups. Previous work like the conceptual model from NIST (National Institute of Standards and Technology) had shown that, in order to distinguish between various aspects of Smart Grid solutions, more than one viewpoint has to be covered.

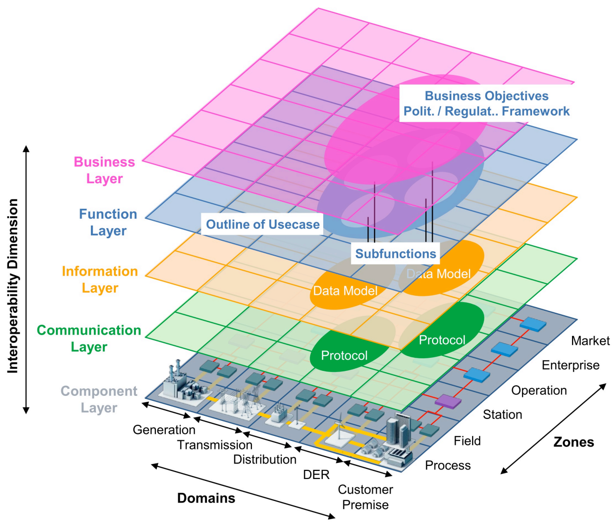

Figure 1: The SGAM model

Based on the original scope, the SGAM can be considered only a reference designation system rather than a reference architecture model [1].

The concept of reference designation is derived from the original physical hardware design process in order to allocate certain parts. As per definition, a reference designator unambiguously identifies a component in an electrical schematic or on a printed circuit board. The reference designator usually consists of one or two letters followed by a number, e.g. R13, C1002. The number is sometimes followed by a letter, indicating that components are grouped or matched with each other, e.g. R17A, R17B. The IEEE 315 series contains a list of Class Designation Letters to use for electrical and electronic assemblies. For example, the letter R is a reference x for the resistors of an assembly, C for capacitors, K for relays. Those schemes can be found in the power grid as well, e.g., in the IEC 61850 LN naming rules.

Very little rules for filling out SGAM model cubes actually exist, shapes are not defined by some kind of standard, the focus is on the reference designation system. Filling out an SGAM model can be considered as some kind of „visual keywording“, providing a way to put each part embodied in a smart grid solution in context of the value chain, interoperability dimension and internal utility organization [3]. The aspect of reference is defined by the content modeled in this reference designation system, the requirements and functions for a solution can act as a blue-print for own developments. Within various projects, SGAM has proven to be a very useful tool for knowledge sharing about Smart Grid solutions [3-7]. Within this context, various new SGAM based models have been developed which are described and discussed in [1]. Those models focus on home and building architecture management (HBAM), the so called Smart City Infrastructure Architecture Model SCIAM, the Electric Mobility Architecture Model (EMAM, [6]), the Maritime Architecture Framework MAF [13] and, of course, the RAMI 4.0 [10, 11] discussed in this very contribution.

The derivates typically follow the interoperability stack rules for the technical solutions as defined by the SGAM because those viewpoints are usal a natural fit for technical development projects. Some basic design rules have to be followed in order to make various metrics, style guides and tooling work with the new model [1]. The approach presented in this paper takes advantage of the fact that the RAMI shares a lot of basic design principles with the SGAM, thus, making a transfer of the SGAM visualization to the domain of Industrie 4.0 possible. The next section will provide a very brief introduction to the RAMI model, focusing on the most striking changes from the modeling paradigm point of view.

1.2 RAMI 4.0 – Reference Architecture Model Industry 4.0

The Reference Architecture Model for Industry 4.0 (RAMI 4.0) [10] is the most sophisticated derivative of the SGAM as of today, developed by ZVEI in Germany. Based on the German Industrie 4.0 concept, the main aspect is the re-use of the GWAC interoperability stack. In addition to business, function, information, communication and asset representing component, a new layer called integration is introduced. The domain and zone axis are not custom taxonomies but are based on the IEC 62890 value stream chain or the IEC 62264/61512 hierarchical levels, respectively.

The main purpose of the model is defined by ZVEI as follows: The model shall harmonize different user per-

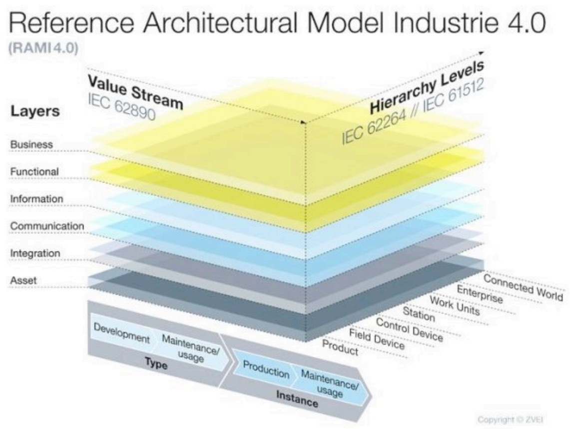

Figure 2: The RAMi 4.0 model by ZVEI

spectives on the overall topic and provide a common understanding of the relations between individual components for Industrie 4.0 solutions. Different industrial branches like automation, engineering and process engineering have a common view on the overall systems landscape. The SGAM principle of having the main scope of locating standards is re-used in the RAMI paradigms, also using it as a reference designation system.

The next steps for proceeding with the modelling paradigm of RAMI 4.0 is to come up with so called 101 examples for Industrie 4.0 solutions in the RAMI, provide proper means for the devices to be identified and provide discovery service modeling for those devices, harmonize both syntax and semantics and focus on the main aspect of the integration layer which was introduced in order to properly model the communication requirements in factory automation.

Within this contribution, we visualize an example from the factory automation domain, a model of a yoghurt filling plant provided by Pepperl+Fuchs Group. One issue of reference designation model modeling is finding good examples for the users to give them a hint how to use the three-dimensional model. The RAMI 4.0 has taken over a similar approach to the SGAM, focusing on providing meaningful PowerPoint based two-dimensional, narrative examples. One drawback when applying the method chain form the Smart Grid to the Industrie 4.0 scope is that there is no harmonized, common meta-model template like the IEC 62559-2 for Smart Grids [7]. For the overall scope, this is not much of a problem since the RAMI will cover a systems engineering approach where standardized tools and languages for requirements engineering like SysML, ReqIF and tools like Rational DOORS or Sparx Enterprise Architect exist. However, a common meta-model of a requirements elicitation template and the architecture model would make for an easier transformation and creation of test models.

In the next section we are going to present our approach to visualizing RAMI models based on a common SGAM tool. The original tool was developed with the paradigm of excluding hardcoded domains, zones and layers and could be easily adopted. The solution is a browser-based, hosted service for rendering with an import interface for Spreadsheet based node-edge based models.

Within figure 6, the spreadsheet created from the yoghurt filling machine example is depicted.

2 Visualizing the RAMI 4.0 model

In order to properly communicate about the models, a fully navigable 3D model has been developed which is depicted in figure 4 of this paper.

The tool can import models, and in addition to graphics, show metadata on the objects visualized in the RAMI 4.0 stack. In addition, various manipulations like omitting individual layers, rotation, slicing and exporting graphics to PNG; JPG can be performed.

Therefore, the tool can also act as a modeling tool to visualize generic RAMI node-edge based graphs that can be easily converted from formal CSV files to generated graphics for presentation in meetings or needed documentation.

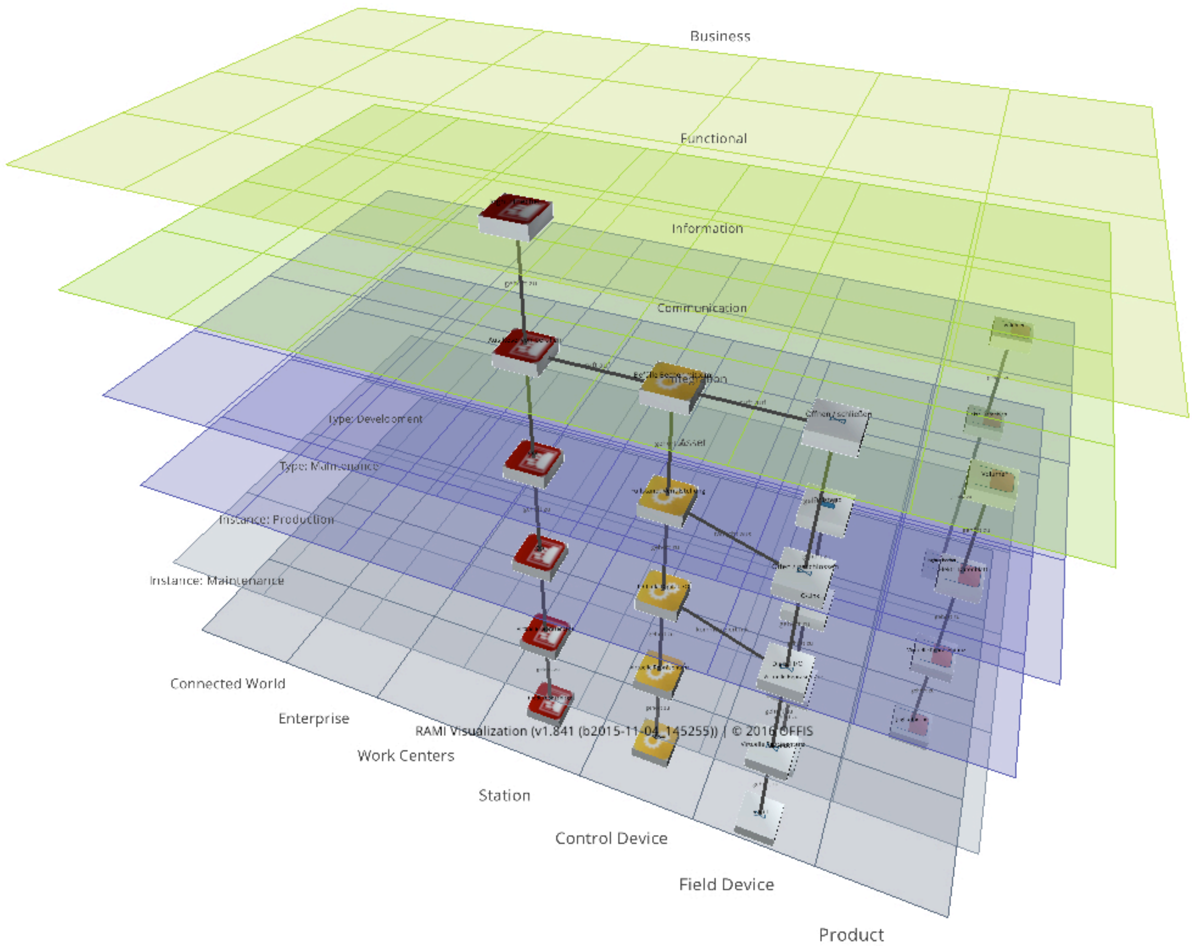

Figure 4: RAMI example full screen mode

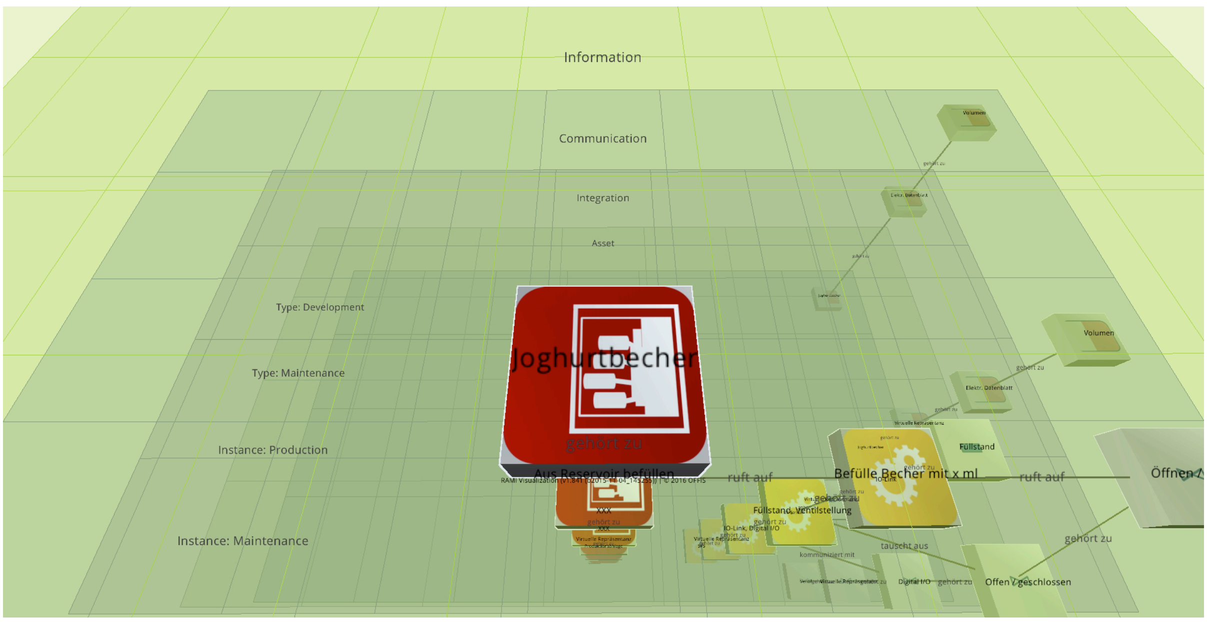

Figure 3: RAMI Zoom in on Intelligent Product

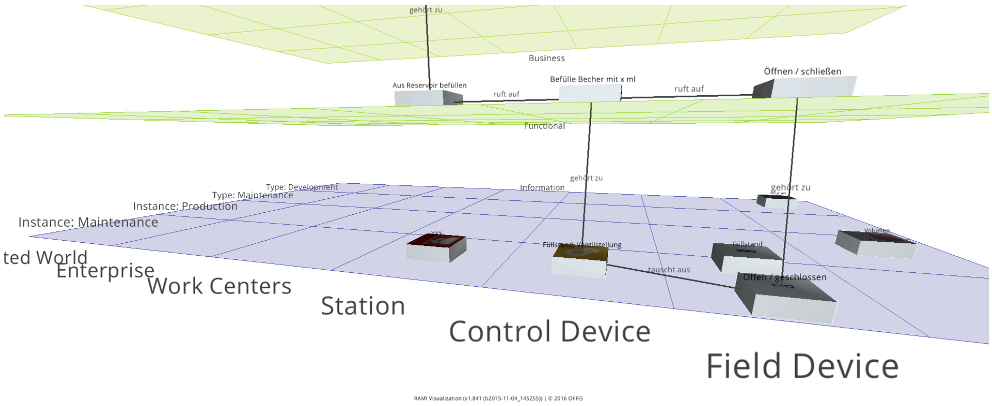

Figure 7: Zoom In on Asset Layer

	A	B	C	D	E	F	G
1	ID	Name	Type	Description	Layer	Domain	Zone
2	B1	Volumen	Becher		Information	Type: Development	Product
3	B2	Elektr. Datenblatt	Becher		Communication	Type: Development	Product
4	B3	Joghurtbecher	Becher		Asset	Type: Development	Product
5	B4	Volumen	Becher		Information	Instance: Production	Product
6	B5	Elektr. Datenblatt	Becher		Communication	Instance: Production	Product
7	B6	Virtuelle Repräsentanz	Becher		Integration	Instance: Production	Product
8	B7	Joghurtbecher	Becher		Asset	Instance: Production	Product
9	S1	Füllstand	Sensor		Information	Instance: Maintenance	Field Device
10	S2	IO-Link	Sensor		Communication	Instance: Maintenance	Field Device
11	S3	Virtuelle Repräsentanz	Sensor		Integration	Instance: Maintenance	Field Device
12	S4	US-Sensor	Sensor		Asset	Instance: Maintenance	Field Device
13	V1	Öffnen / schließen	Ventil		Functional	Instance: Maintenance	Field Device
14	V2	Offen / geschlossen	Ventil		Information	Instance: Maintenance	Field Device
15	V3	Digital I/O	Ventil		Communication	Instance: Maintenance	Field Device
16	V4	Virtuelle Repräsentanz	Ventil		Integration	Instance: Maintenance	Field Device
17	V5	Ventil	Ventil		Asset	Instance: Maintenance	Field Device
18	C1	Befülle Becher mit x ml	Steuerung		Functional	Instance: Maintenance	Control Device
19	C2	Füllstand, Ventilstellung	Steuerung		Information	Instance: Maintenance	Control Device
20	C3	IO-Link, Digital I/O	Steuerung		Communication	Instance: Maintenance	Control Device
21	C4	Virtuelle Repräsentanz	Steuerung		Integration	Instance: Maintenance	Control Device
22	C5	SPS	Steuerung		Asset	Instance: Maintenance	Control Device
23	A1	Joghurtbecher	Anlage		Business	Instance: Maintenance	Station
24	A2	Aus Reservoir befüllen	Anlage		Functional	Instance: Maintenance	Station
25	A3	XXX	Anlage		Information	Instance: Maintenance	Station
26	A4	XXX	Anlage		Communication	Instance: Maintenance	Station
27	A5	Virtuelle Repräsentanz	Anlage		Integration	Instance: Maintenance	Station
28	A6	Produktionsanlage	Anlage		Asset	Instance: Maintenance	Station

	A	B	C	D
1	From	To	Type	Name
2	B1	B2	dependency	gehört zu
3	B2	B3	dependency	gehört zu
4	B4	B5	dependency	gehört zu
5	B5	B6	dependency	gehört zu
6	B6	B7	dependency	gehört zu
7	S1	S2	dependency	gehört zu
8	S2	S3	dependency	gehört zu
9	S3	S4	dependency	gehört zu
10	V1	V2	dependency	gehört zu
11	V2	V3	dependency	gehört zu
12	V3	V4	dependency	gehört zu
13	V4	V5	dependency	gehört zu
14	C1	C2	dependency	gehört zu
15	C2	C3	dependency	gehört zu
16	C3	C4	dependency	gehört zu
17	C4	C5	dependency	gehört zu
18	A1	A2	dependency	gehört zu
19	A2	A5	dependency	gehört zu
20	A5	A6	dependency	gehört zu
21	V1	C1	invokes	ruft auf
22	V2	C2	information	tauscht aus
23	V3	C3	communicat	kommuniziert mit
24	C1	A2	invokes	ruft auf

Figure 6: Input format for the 3-D Renderer

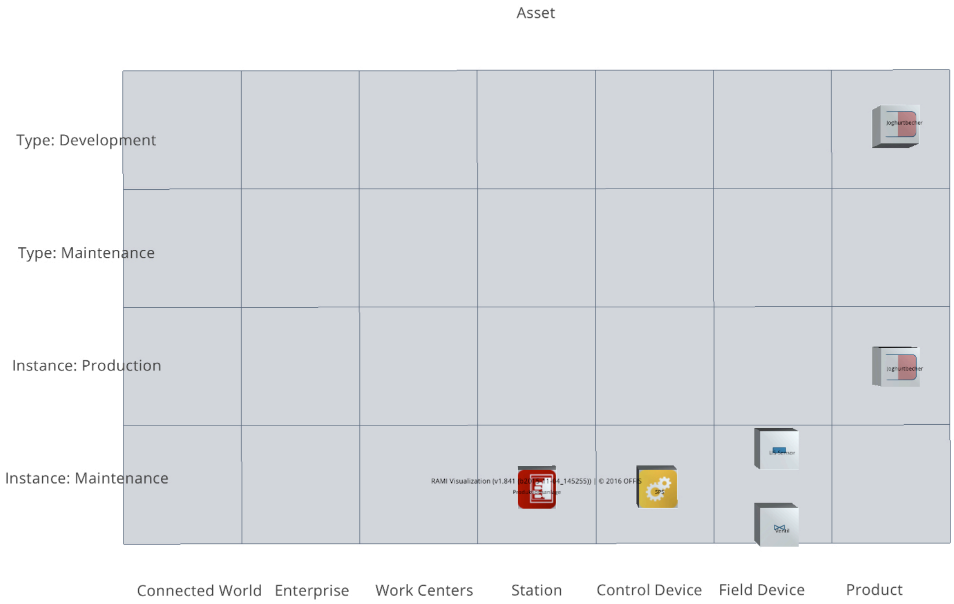

Figure 5: 2-D Export of a single layer from the tool

3 Future Work and Scope

Within this contribution, we have motivated the way to proceed from the SGAM toolchain-based on the M/490 work [14] to new reference designation systems [1]. The SGAM [2] has proven to be a useful solution for visualizing technical solutions in the smart grid, containing various use cases and tools [3]. Based on the SGAM and the corresponding tools like e.g. the SGAM toolbox [4], a system of systems approach was developed, also containing analysis functions for non-functional requirements like security [4, 5]. Early approaches have shown a possible transfer to other domains like smart cities [7, 9] or electric mobility [6] and the maritime domain [12].

One of the most important new initiatives is the RAMI 4.0 model for Industrie 4.0. Based on the specification by DIN [10], we have outlined the need to model the RAMI also as a communication tool about the solutions to be implemented in the context of a structured requirements analysis and formalization process. In addition to Microsoft Visio as well as Microsoft PowerPoint templates already known from the SGAM context, we have developed a rendering for RAMI 4.0 based on an open data format (ODS, Open Data Spreadsheet) for a web-based application.

The 3-D model can be rotated, individual layers can be activated or de-activated and different models can be loaded simultaneously. In addition, the pictures shown within this contribution are either direct PNG or JPG exports from the tool, showing that a quick and useful visualization for e.g. presentations in stakeholder meetings can be created with very little modeling effort needed. The rendered entities can have various shapes as well as textures which can be fully configured in the client (i.e. the browser) used. The solution is browser based, supports most current browsers and needs no installation of plug-ins or runtime environments.

In the future, a model repository as well as a so called RAMI 4.0 toolbox in Sparx Enterprise architect will be developed, providing the same functionality for the development process as the SGAM toolbox for the Smart Grid and making export to the rendering format possible. In addition, new models in the context of Industrie 4.0 will be modeled, e.g. the ju-RAMI with links to the corresponding laws at http://www.gesetze-im-internet.de, providing a visual navigation tool for the contents of the ju-RAMI. In addition, work on modeling the Industrial Internet Reference Architecture (IIRA) from the Industrial Internet Consortium (IIC) wil provide the possibility to render and load both ICC as well as RAMi 4.0 models in one tool and find, e.g., semantically equivalent services [13].

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