Towards Translation of Semantics of Automotive Interface Description Models from Franca to AUTOSAR Frameworks

An Approach using Semantic Synergies

Sangita De, Michael Niklas,Brian Rooney
Corporate System and Technology SW Continental Automotive GmbH
Regensburg, Germany
{sangita.de, michael.niklas, brian.rooney} @continental-corporation.com,sangita@students.zcu.cz

Juergen Mottok
Dept. of Electrical Engineering and Information Technology
OstBayerische Technical University (OTH)
Regensburg, Germany
juergen.mottok@oth-regensburg.de

Premek Brada
Dept. of Computer Science and Engineering, Faculty of Applied Sciences
University of West Bohemia
Pilsen, Czech Republic
brada@kiv.zcu.cz

Abstract –**The automotive industry is eventually evolving into a complex network of services. The heterogeneous and distributed nature of automotive software systems demands flexible software components which can operate in different environments. Because of heterogeneous automotive development environments, the domain experts, must cope with too many diversities, adaption layers, and incompatibilities to design applications for the current generation of autonomous driving vehicles. In this context, interface adaptation is a promising approach to achieve flexibility without directly changing the respective components. AUTOSAR, which is the de-facto standard for describing automotive system architecture and is a hugely comprehensive standard allowing designers full control from abstract system description to bare metal level deployment. However, the vehicle subsystems have still evolved to include multifarious high-level domains not covered by AUTOSAR e.g. Infotainment, Telematics etc. Therefore, it seems beneficial to bridge the semantic gaps between AUTOSAR applications and other standards of automotive application domains. The goal of this paper is to investigate interface semantic mapping and achieve transparent integration of domain-specific applications using the translation of semantics among the AUTOSAR platform software component models and other software components models of open source development platforms e.g. GENIVI. A key goal of such a modelling approach is the reuse of existing interface description languages and respective code generators. This will enhance future interoperability and decrease in incompatibility among these platforms.**

Keywords-component, Framework; semantic; traits; synergy; Franca IDL; component model; vehicle; interface; ARXML.

I. INTRODUCTION

In the current state of the automotive industry, most of the vehicle application (app) interfaces must be specified in various formalized formats to fulfill the specific semantic requirements in framework (FW) specific programming language syntax. The Interface Description Language (IDL) model is used to describe the communication behavior of the software components (SWCs) for a FW, using an implementation independent semantic and syntactic notation [2][7]. The syntax of an IDL is a possibly infinite set of legacy elements which is expressed by relating the syntax to a semantic domain. Over the past few years, there has been an increase in demand for integration with legacy and 3rd party for vehicle functions such as autonomous driving, Car-2-x, etc. Consequently, there is a demand for the development of an integrated system in which an automotive app component and an infotainment app component interoperate with each other. Thereby the former is a part of the AUTOSAR system and the latter is a part of the GENIVI system. Model-to-model mapping is often employed to establish a translation of app interface semantics between these heterogeneous platforms of automotive app domain using semantic synergies.

Both AUTOSAR standard FW and Franca FW used by GENIVI standard uses communication technologies that are based on model definitions. This opens the further possibility to translate using model-to-model transformation methods that can improve software quality, performance, and reduction in development time and engineering costs [1]. For the description of SWCs models at app level GENIVI standard uses Franca IDL and both the platforms of AUTOSAR standard namely, AUTOSAR Classic and AUTOSAR Adaptive uses a common exchange format or an IDL that is ARXML (AUTOSAR XML) for the description of SWCs models [4].

For a model-to-model transformation, the desired translation of semantics can be in either direction. Using a Franca connector as an app interface semantic translator, the target of translation that is achieved can be either a Franca instance model (AUTOSAR-to-Franca translation) or an AUTOSAR SWC description (Franca-to-AUTOSAR translation). In the current scope of research, we have attempted to investigate the translation of interface semantics at app level, in the

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direction from Franca-to-AUTOSAR, based on exploration of synergies. Such a translation includes only translation of specification of interfaces (of Franca IDL) and data types to semantically equivalent interfaces and datatypes represented in an AUTOSAR XML or ARXML.

A. *FIDL-to-ARXML Model Transformation: The Rationale*

In automotive use cases such as autonomous driving, there are proposals for ECU (Electronic Control Unit) with multiple CPU (Control Processing Unit) core partitions and there is a high probability that a vehicle infotainment app SWC of a FW running in one partition of a vehicle ECU to communicate with the automotive software app component of a different FW in another partition of ECU, without directly changing the respective components. This would require interface adaption or transformation at the component model level to achieve transparent peer-to-peer communication, as can be seen in Figure 1. This scenario could be due to: firstly, the increase in requirement for integration with 3rd party and legacy components, secondly, requirement of a huge number of communicating processors for cross-platform communications and lastly, increase in non-functional requirements such as software quality and performance.

GENIVI standard uses an open source FW i.e. Franca (aligned with GENIVI standard) IDL for bridging the gaps between the different automotive IDLs by using a formal model-to-model transformer encapsulated as Franca Connectors [1][8]. Franca connectors are based on semantic mapping of different automotive FW's IDLs, which should be integrated together to share FW specific app component services. At the model level, Franca Connectors enhances interoperability and allows AUTOSAR ECU and a GENIVI IVI (In-Vehicle-Infotainment) system to perform joint functionality[1]. Additionally, Franca connectors can use code generators to generate source code and configuration files from the transformed models.

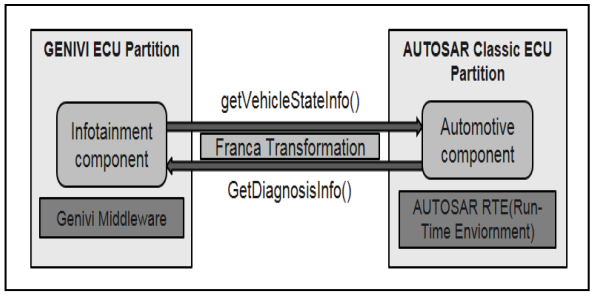

Figure 1. Overview of cross-framework communication between GENIVI and AUTOSAR system.

B. *Contribution of the Report*

To achieve interoperability and transparent communication between AUTOSAR automotive app component and GENIVI infotainment app component at the model level, it is required to work out a conceptual semantic mapping between the two platforms app component interfaces. A typical AUTOSAR SWC port is typed by an interface. An AUTOSAR Classic SWC operation can only be contained in a client-server interface and a data element can only be contained in a sender-receiver interface. Therefore, to translate semantics from Franca FW IDL (fidl) to AUTOSAR FWs IDL (arxml) requires at least two AUTOSAR Classic (namely Client Server and Sender Receiver interface) or one AUTOSAR Adaptive Service Interface, to be generated for one Franca interface to represent equivalent methods, attributes and broadcasts. The goal of this paper is to compare the traits of ARXML and FIDL, using static one-to-one model element mapping and to explore the synergies or commonalities in these traits required for the translation of semantics .Mapping of semantics of Franca normal methods to AUTOSAR Classic client-server interface operations, Franca fire-and-forget methods to AUTOSAR Classic sender-receiver interface and Franca broadcasts to AUTOSAR Classic data elements, are manually investigated using static semantic mapping approach.

C. *Related Work*

An Automotive app SWC modelling is a fundamental aspect of the automotive industry and is becoming increasingly collaborative. In 2016, the concept for *Franca Connectors* was proposed aligned with AUTOSAR [1]. The goal of Franca Connectors was to obtain two consistent complete descriptions of the app level of a system that consists of AUTOSAR parts and parts that are described with the Franca IDL: one as an AUTOSAR SWC description and one as a Franca model. However, a Franca model only addresses the type level: component types and data types whereas an AUTOSAR description also specifies component instances (called prototypes) and their connections, which is still absent in Franca, but could be included in future Franca+. In 2018, the Generic Protocol Evaluation Project Team identified SOME/IP and Franca IDL (used together with CommonAPI bindings) as two of the preferred automotive app domain options [6] for vehicle domain interaction strategies. The team proposes a tool that uses model-to-model transformation to achieve a compatible code generation on both sides of ARA::COM (AUTOSAR Runtime Environment for Adaptive App Communication) and Franca IDL.

In 2012, the authors of [2] propose model-to-model transformations to be employed to establish translation of semantics by semantic mapping of programming languages of heterogeneous platforms. The authors of [2] deal with the co-adaptation problems by proposing higher-order model transformations which take a difference model recording the metamodel evolution and produce a model transformation able to co-evolve the involved models. The authors of [8] propose a novel adapter with static and dynamic features for building flexible interfaces for variable automotive software systems.

II. METHODOLOGY

This section provides an overview of using Franca Connectors as IDL model transformers for translation

of interface semantics from Franca interface instances to AUTOSAR SWC instances using semantic mapping. The static semantic analysis of IDLs is at a conceptual stage and is carried out manually to explore the synergies in the semantic traits of AUTOSAR and Franca FW specific IDL models. However, the mapping of datatypes from Franca IDL to AUTOSAR ARXML is not considered in the current research scope. A *link* that is used by a Franca Connector has an AUTOSAR classic side and a Franca side and is intended in the sense of the intended communication flow. The AUTOSAR side is always given by a port instance reference, that is a *SwComponentPrototype* [3].

A. *Static Semantic Mapping of Franca IDL to AUTOSAR Classic Client Server Interface*

Each AUTOSAR Classic SWC port is typed by an interface which may be a client-server interface or a sender-receiver interface for signal-based communication. In the first case, it contains operations that are either offered (provided) or required at the port. In the second case, it contains data elements that are either sent (provided) or expected (required) at the port. A simple case study on OTA (Over-the-Air) vehicle *Software_Update* SWC has been considered for semantic mapping of attributes, method(normal) and arguments of Franca IDL to AUTOSAR Classic *ClientServerInterface*, as can be seen, Figure 2. In the OTA software update scenario, an AUTOSAR SWC port requests a Franca update method (e.g. *m*) from a Franca instance1 using a link can be seen in Figure 2.

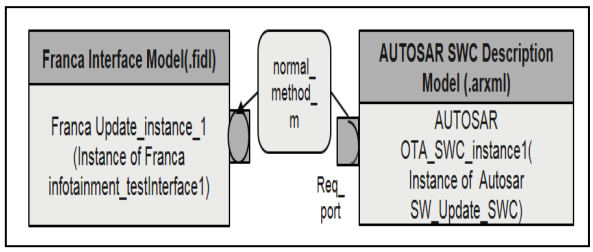

Figure 2. Example of Franca Interface to AUTOSAR Client Server Interface Mapping

In Figure 2. Franca Instance refers to an instance of Franca Interface and is used to implement an interface. The high-level semantic synergies observed between Franca IDL attributes, normal methods, and arguments to *ClientServerOperation,* interface and *ArgumentDataPrototype* of AUTOSAR Classic SWC in ARXML representation [3], can be seen in the TABLE I. (marked with *). The getter operation by default always corresponding to a Franca attribute. However, if the Franca flags are *readonly* or *noSubscriptions* are set, the generation of the setter operation and the notification data elements respectively are prohibited [1]. The semantic synergies explored with semantically mapping of Franca IDL to AUTOSAR Classic ARXML representation of Client Server Interface can be used by IDL model-to-model transformer for translation of semantics using a common interface description from Franca IDL to ARXML or vice-versa.

TABLE I. STATIC SEMANTIC MAPPING FOR CLIENT-SERVER INTERFACE FROM FIDL TO ARXML

FIDL	ARXML
Normal _Method	ClientServerInterface :: ClientServerOperation*
Argument	ArgumentDataPrototype*
Attribute: Getter	ClientServerOperation*
Attribute: Setter	ClientServerOperation*
Attribute: Notification_Data Element	VariableDataPrototype*

B. *Static Semantic Mapping of Franca IDL to AUTOSAR Classic Sender Receiver Interface*

The template is used to format your paper and style the text. In contrary to the methods and broadcasts, that are provided by a Franca interface instance, the fire-and-forget methods are interpreted as data elements that are required by the Franca instance and are semantically mapped to AUTOSAR Classic Sender Receiver Interface for receiving data elements from the later [1] .A simple case study on *Emergency_Brake_Control* SWC has been considered for semantic mapping of Franca IDL's fire-and-forget method and broadcasts to AUTOSAR Classic sender receiver interface, as can be seen in Figure 3.

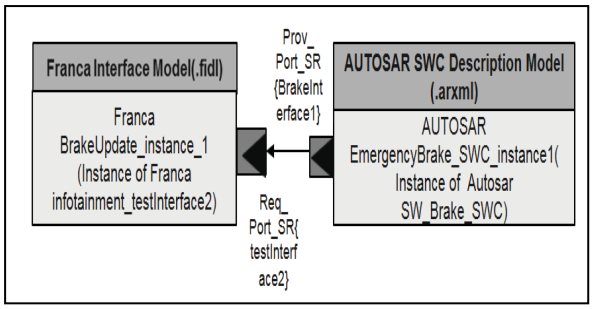

Figure 3. Example of Franca Interface to AUTOSAR Sender Receiver Interface Mapping

The high-level semantic synergies observed between Franca IDL fire-and-forget method, provided or required data elements and broadcasts to *SenderReceiverInterface* and *DataElements* (*VariableDataPrototype)* of AUTOSAR Classic SWC in ARXML representation [1], can be seen in TABLE II. (marked with *): The semantic synergies explored with semantically mapping of Franca IDL to AUTOSAR Classic ARXML representation of Sender Receiver Interface can be used by IDL model-to-model transformer for translation of semantics from Franca IDL to ARXML or vice-versa.

TABLE II. STATIC SEMANTIC MAPPING FOR SENDER-RECEIVER INTERFACE FROM FIDL TO ARXML

FIDL	ARXML
FireAndForget _Method	SenderReceiverInterface :: DataElements (VariableDataPrototype)*
FrancaProvDataElements	DataElements (VariableDataPrototype)*
FrancaReqDataElements	DataElements (VariableDataPrototype)*
Broadcasts	SenderReceiverInterface (1: n) :: DataElements (VariableDataPrototype)*
Attribute: Notification_Data Element	DataElements (VariableDataPrototype)*

C. *Static Semantic Mapping of Franca IDL to AUTOSAR Adaptive Service Interface*

The IDL model of a Service Oriented Architecture (SOA) based vehicle app FW such as AUTOSAR Adaptive, usually describes the services that are offered or required by a vehicle app in an abstract form, independent of implementation details. Each operation on an AUTOSAR. In TABLE III. *FAttribute* refers to attributes used by Franca IDL. The AUTOSAR Adaptive app component description is represented using ARXML. The service interface model of AUTOSAR Adaptive automotive platform is specified using various elements [4], these includes:

- Aggregation of *Client-Server Operations* in the role of *Methods*;
- Aggregation of variable data prototypes in the role of *Events*;
- Aggregation of Meta-class Fields or data with read/write semantics in the role of *Fields.*

The *Methods*, *Events,* and *Fields* of AUTOSAR Adaptive service interface are semantically mapped to Franca IDL's *Methods*, *Broadcasts* and *Attributes*[6]. Fields in context of service interface represent a data value hosted by the server to be accessed by one or more clients using accessors getter or setter or notifiers, provided the required accessor attribute of the Method is set to *true* [1]. Similarly, semantic mapping of Franca IDL *Fire-and-Forget Method* to AUTOSAR Adaptive app service interface can be achieved by activation of the "fire & forget" semantics of a given method by setting the value of attribute *method.fireAndForget* to value *true* [4].

AUTOSAR Adaptive uses ARA::COM communication API (Application Program Interface) specification for inter-domain communication between the vehicle FWs. In this context, messages are semantically translated from Franca CommonAPI to AUTOSAR Adaptive ARA::COM at runtime. The goal of such translations is to apply code generation by AUTOSAR Adaptive-compatible code generators as well as Franca-compatible generators (e.g., CommonAPI C++) in a way that leads to transparent communication between both systems at runtime.

TABLE III. STATIC SEMANTIC MAPPING FOR SERVICE INTERFACE

Franca IDL	ARXML
Attributes:Notification (hasNotifier =! FAttribute.noSubscriptions)	Fields:Notification (field.hasNotifier = Boolean)*
Attributes:Getter (hasGetter =! FAttribute.noRead)	Fields:Getter (field.hasGetter = Boolean)*
Attributes:Setter (hasSetter =! FAttribute.readonly)	Fields:Setter (field.hasSetter = Boolean)*
Method: Fire-and-Forget (without flag)/Normal_Method	Method: Request-Response (ClientServerOperation)*
Method: Fire-and-Forget Method (with flag)	Method: Fire-and-Forget Method (method.fireAndForget = Boolean)*
Argument	ArgumentDataPrototype*
Broadcast	Events (VariableDataPrototype)*

III. SCOPE OF IDL MODEL SEMANTIC TRANSLATION

Based on the conceptual static semantic mapping, the syntactic description of interfaces using Franca FIDL model is model transformed to AUTOSAR ARXML model to achieve seamless integration and transparent cross FW communication between these FWs. The study on IDL semantic mapping at app component model level and exploration of semantic synergies is a knowledge base for future model transformers prototype models. Using Franca connectors as model transformers, the semantics of FIDL can be translated to AUTOSAR Classic ARXML. The abstract pseudo code for semantics translation can be seen in Figure 4.

The current scope of model transformation from FIDL to AUTOSAR Classic ARXML is limited. Unlike AUTOSAR app FWs , Franca app FW does not include SWC model descriptions. The AUTOSAR Classic platform processes require that all the inter-operations among various app component instances that may occur during runtime are declared statically in the AUTOSAR Classic SWC description [1]. On the contrary, inter-operations in an infotainment system from GENIVI are typically dynamic. Therefore, for the AUTOSAR Classic and the GENIVI app component interfaces that shall inter-operate must be known and identified at design time [1] [3].

```
/*Franca Connector*/
Connector Connector_Fr {

/*instances*/
instances {
franca_instance instance_1 implements
testInterface1}
connections {

/* ComponentPrototype calls method on
Franca instance_1*/
c1 autosar_port
ARRoot.Composition:ComponentPrototype
:ARRoot.ComponentType.Rport_ClientSer
ver ->
franca_instance_1:testInterface1
```

Figure 4. An abstract model of Franca Connector

AUTOSAR Adaptive platform supports dynamic inter-operations in automotive systems like the infotainment system from GENIVI. Using Franca adapters (similar in functionality to Franca Connectors) as model transformers, the semantics of FIDL can be translated to AUTOSAR Adaptive ARXML[8][5][6]. The Semantics of messages (including *Methods, Attributes* and *Broadcasts*) of Franca FW represented using FIDL and CommonAPI bindings, are translated to AUTOSAR Adaptive service interface messages represented using ARXML and using ARA::COM (program interface used by AUTOSAR Adaptive platform) bindings, as can be seen in Figure 5.

```
/*Franca Stub adapter to connect to
AUTOSAR Adaptive Remote Event
Handler*/
StubAdapter StubAdapter_Fr {
IDrivingLaneStub::IDrivingLaneStub
():   remoteEventHandler_,
testinterfaceVersion_(IDrivingLane::g
ettestInterfaceVersion()) {}

/*CommonAPI:  method to get Client
ID*/
CommonAPI::Version &
IDrivingLaneStub::gettestInterfaceVer
sion
(shared_ptr<CommonAPI::ClientId>) {
    return testinterfaceVersion_;}

/*CommonAPI Client to SOME/IP Proxy
(Service Receiver) Address translator
using shared pointer */

shared_ptr  <CommonAPI::SomeIP::Proxy>
createIDrivingLaneSomeIPProxy(
CommonAPI::SomeIP::Address &_address,
shared_ptr<CommonAPI::SomeIP
::ProxyConnection> &_connection) }
```

Figure 5. An abstract model of Franca Connector(or Adapter)

Figure 5. illustrates pseudo code using SOMEIP IP (Scalable service Oriented MiddlewarE over IP) communication protocol. SOMEIP is based on RPC (Remote Procedure Call). It is also the commonly used communication protocol by Franca and AUTOSAR FWs for the exchange of data over the network (via ethernet), as can be also seen in Figure 6. The interface model transformer prototype is based on translation of interface semantics from FIDL to ARXML concepts. Figure 6. Illustrates input source of the model transformer prototype as the Franca app interface model and the generated target as the AUTOSAR app SWC interface model. However, the model transformer prototype can be also configured for bidirectional translation of semantics in future.

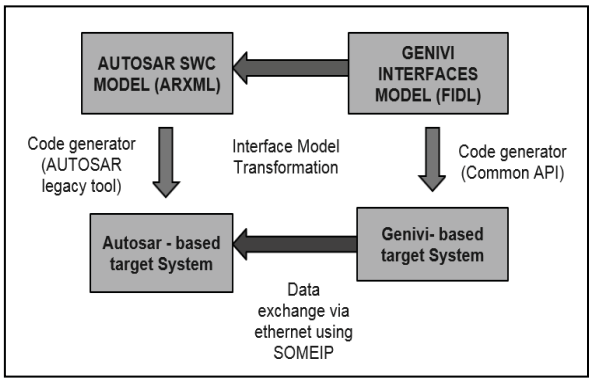

Figure 6. An abstract model of Franca-AUTOSAR app interface model transformer prototype

Using the Franca to AUTOSAR interface model transformer prototype, a typical example model of Franca FIDL to AUTOSAR Classic ARXML semantic translation of a SeatHeatingControl(SHC) vehicle app SWC interface, can be seen in Figure 7.

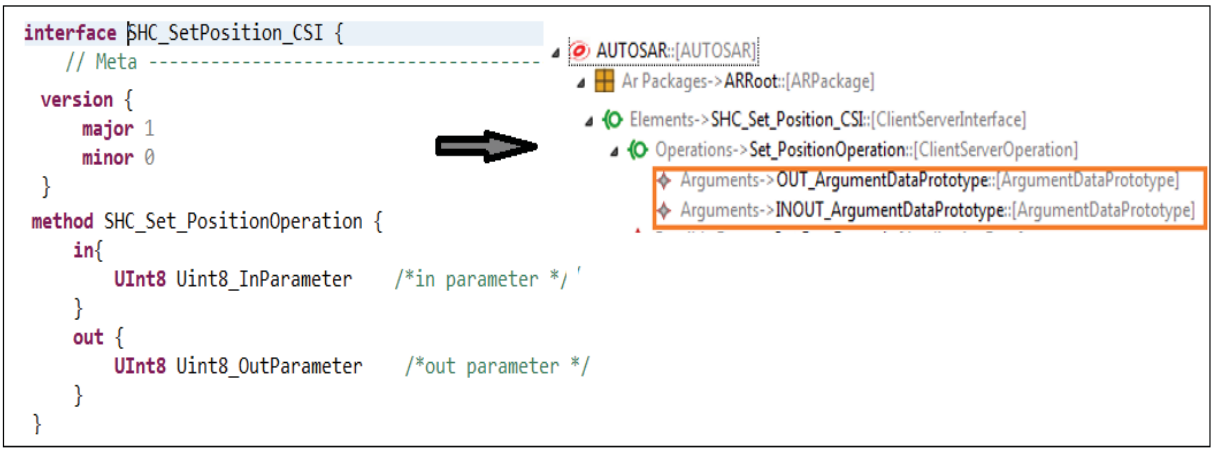

Figure 7. A typical example model of Franca to AUTOSAR Classic app interface semantic translation using a SHC case study

IV. CONCLUSION

This paper proposes an approach to translate semantics from Franca FIDL to AUTOSAR ARXML at vehicle app model level. For the translation of interface semantics, we have considered a vehicle app component using FIDL as a source interface model and target interface model as app component using ARXML. Despite of syntactic differences, the translation of interface semantics is based on semantics commonalities observed among the app IDL models of Franca and AUTOSAR FWs. We have tried to demonstrate the semantic mapping and translation of the IDL fundamental traits by using relevant vehicle app SWC case studies. The translation of IDL model semantics with the adaption to syntactic representation of target FW (AUTOSAR) IDL model, deals with the occurrence of multiple change types in the app SWC metamodel to cope with the realistic scenarios.

In specific, the IDL model differences must be decomposed in resolvable and non-resolvable changes to achieve transparent integration and flexible cross-communication of vehicle app SWCs of the source and target FWs. Due to still fundamental differences between Franca and AUTOSAR app SWC meta-model, the approach used was forced to make concrete assumptions to achieve a mapping. These assumptions are usually based on some design time decision around the intended usage of a specific model element. Therefore, any transformation tool must either make the same concrete decision or make some configuration provision in either the tool itself or the language itself. The conceptual semantic mapping approach used in current scope for comparison of FIDL and ARXML models of the infotainment and automotive systems is a manual and a static approach and could be used for bidirectional translation of semantics in future to enhance interoperability between the two FWs.

A manually operated adaptation or IDL model translation methodology is error-prone and can give place to inconsistencies which can possibly lead to irremediable information erosion. Therefore, there is an on-going research proposal in automotive industry to automate the translation of interface semantics from FIDL to ARXML using a model transformer prototype for future vehicle app domain usecases. Comparatively, the AUTOSAR SWC meta-model allows a vehicle app designer more freedom to dig deeper at every meta-model level than Franca, which is typically scoped at the communication matrix level. Additionally, AUTOSAR has been accepted as a de-facto standard for automotive software architecture. Between AUTOSAR standard flavors, Adaptive AUTOSAR has inherently a closer binding to Franca and vice versa. To some progress extent, GENIVI introduces a novel standard Franca+ which may address the deviations between FIDL and AUTOSAR Adaptive and but, yet that standard is still in incubation. To deal with these deviations, we plan to extend our work of manual translation of semantics of Franca FIDL to AUTOSAR ARXML in this direction.

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