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General concepts: semantics as the basis of interoperability

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Abstract

This document contains an overview of the general concepts on how data semantics is interpreted in the Arrowhead Tools project, serving as a conceptual basis for interoperability notions. In particular, it provides a basic high-level definition of semantics itself, identifies three conceptual categories where a semantics might be considered, and, finally, gives a guideline for identifying/placing a particular approach in this semantic framework.

ECSEL EU project 826452 - Arrowhead Tools
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1. Semantics as the basis of interoperability

This document offers a more detailed explanation of how different semantic approaches serve as the basis of interoperability in the Arrowhead Tools project.

Interoperability is a core concept of Arrowhead, addressing not only (actually, typically not) the communication between IoT devices within an SoS, but rather the ways of data being exchanged between different tools within the scope of Arrowhead Tools.

For the general definitions of what characterizes an Arrowhead tool, refer to the document **O1** in the same delivery as this document (**D4.1**). We just recall here that interoperability is central to the concept of a *toolchain*, i.e., a sequence of tools where the output of a tool in the sequence is consumed by the subsequent tool (except for the last member of the chain).

The present delivery serves as a starting collection of ideas from the involved partners, which will be the basis of an integrated semantics definition and related design principles in the further iterations of the project.

In this context, the definition of semantics is deliberately loose and can be summarized as follows:

A **semantics** is a collection of notions for describing an interface between different tools, engineering phases or other concepts, optionally along with (a set of) practical scenarios where those notions are applied.

- A semantics can be *formal,* being a mathematically rigorous data structure description as typical for, e.g., verification scenarios, *informal,* being a natural-language explanation of the involved notions, or it might involve both of the above flavors.
- A semantics can be *static,* describing or referring to snapshots of an SoS without addressing change or evolution, *dynamic,* describing or referring to the evolution or environmental interaction of systems or SoSs, or might comprise both.

In the following, intended to serve as an intuitive guideline for interoperability-focused Arrowhead development and engineering activities, we first describe the major categories in which a tool is capable of interaction (Section 1.1). *Note that this is different from interaction in the strict sense of Arrowhead systems:* here, the tools involved might be on different abstraction levels, might provide design-time modeling, validation or verification support, etc. Thus, interoperability is addressed here from a purpose-oriented perspective.

Afterwards, in Section 1.2, we provide a template consisting of basic points which should be evaluated as a preparation whenever an approach is considered as a semantics for Arrowhead Tools. Instantiations of this template can be found in the accompanying document **O5** within this same delivery **D4.1**, being a compilation of the inputs from project partners involved in Task 4.2. In that document the main potential fields of study in this task are outlined.

O5 also contains a discussion on the topic of *translation,* a concept to be thoroughly addressed in the future, to foster interoperability on a semantic level. Such, not tool-specific but rather integrative, translation modules between different semantics would allow to counteract to a certain degree the shortcomings of single tools from an interoperability perspective; however, the actual means to do so still have to be discussed in the future.

1.1 Categories of interaction

A category of interaction refers to the purpose of an interoperability interface of an Arrowhead tool. As a coarse-grained separation of interests, we propose the following categories (possibly to be extended later on), remarking that an actual tool might even address more of them:

- *Design and Modeling:*

  Here, the purpose of a semantics is typically to define a data format, serving as an abstraction or mapping for relating design-time artifacts to their (actual or future) run-time counterparts, possibly not in a 1-to-1 fashion, but rather in the form of a custom-tailored view on the system (or SoS). A typical example of a design-time artifact could be a diagram; in turn, a formal semantics of a diagram might be a meta-model consisting of the concepts appearing on the diagram, while an informal semantics might simply state the meaning of concepts in natural language.

  It is only the presence of a semantics which makes design and modeling tasks interoperable: otherwise, they solely serve representational (visualization) purposes. The (mathematical or language) structure of that semantics might take different shapes, but the overall idea is always to integrate design artifacts into the engineering process and potentially even run-time engineering phases.

- *Data Interpretation:*

  Such an interface allows for creating different views, understandable by other tools or human users, over any collection of system or SoS data. E.g., a query language with a well-defined semantics can be used for extracting features or patterns and to perform structural validation; a reporting and visualization interface might abstract away from existing data for representational purposes; while for a verification approach, we might want to convert the data into a formal structure (e.g., transition systems for model checking) allowing for the inference of properties (reachability, safeness, liveness, etc.)

- *Data Storage:*

  Such an interface summarizes, condensates or extracts data from other system(s) in order to persist it in some other system or tool, for a well-defined and established share access by other systems and tools. This principle can be manifested not only by different database paradigms and their underlying semantics, but also by additional concerns such as versioning (i.e., providing a means for tracking the history of system states) and branching (i.e., dividing the data into different domains or scopes of interest).

1.2 A template for the assessment of semantics

The following points constitute a minimum baseline for considering an approach as part of the Arrowhead Tools interoperability semantics landscape.

A) Name of the approach/tool/standard and the *category of interaction* it belongs to - refer to Section 1 above if applicable.

B) A statement if the approach is attached to a Use-Case within Arrowhead Tools (if yes, with number).

C) An explanation of how the approach supports interoperability and if so - how it will be supported by tools**.** E.g., an abstract model for high-level functional diagrams, serving as an exchange format between systems design and static verification tools.

D) A statement if there is a general-purpose tool for this activity, proposed to be used within Arrowhead Tools, or if a new tool should be developed for this kind of interoperability.

E) Standard exchange format planned to be used for interoperation, if applicable (e.g., JSON, XML, EMF models, …)

F) A statement if the semantics is rather static or dynamic by nature, or if it directly addresses both aspects (see the introductory definition above).

2. Revision history

2.1 Contributing and reviewing partners

Contributions	Reviews	Participants	Representing partner
X		Géza Kulcsár	IQL
	X	Federico Montori	IUNET
	X	Marek Tatara	DAC
	X	Márk Mihalovits	IQL

2.2 Amendments

No.	Date	Version	Subject of Amendments	Author
1	2019-09-30	0.1	First draft	Géza Kulcsár
2	2019-12-10	1.0	Final Sanity Check	Federico Montori, Marek Tatara

2.3 Quality assurance

No	Date	Version	Approved by
1	2019-12-10	1.0	Jerker Delsing