

## STANDARDIZATION FOR ROBOT MODULARITY AND THE INFORMATION MODEL

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Till now, many research institutes and companies have been conducting researches related to robot modularity, but there has been no talk of successful robot modularity in commercial and standard viewpoint. This is because the information provided by each institution is different according to the different perspective of modularity.

The general purpose of modularity can be listed as follows:

- Convenience of development including from design to integration
- Convenience of maintenance

Recently, the robots started to be operated based on the cloud[1], and standardization activity for the safety management system [2] was also started. It can be expected that robots operated in the cloud or safety management system will not consist of robots provided only by one robot vendors. The problem is that the following situation may occur when using robots made by various robot vendors:

- Inventory management of parts used in the various types of robots, which include mechanical and/or electrical parts and software.
- Complex management software.
- : The types of parts and the software API may be different for each robot type.
- : Different types of robots may have different types of communication protocols.
- : Depending on the robot, the emergency management method may be different.

To solve these problems, ISO TC299 WG6 has made a standard for general requirements of robot modularity [3], where the following principles are satisfied: composability, integrability, interoperability, reusability, safety, security. In particular, since safety and security are related to each other depending on the module, risk assessment should be performed considering safety and security at the same time, and after analyzing security-related safety hazards and safety-related security vulnerability, appropriate measures must be provided. Currently, standards for robot-related information model [4-6] are being made so that the general requirement standard of ISO 22166-1 can be easily designed and implemented from a module viewpoint. The term 'information model' has been around for a long time and is being used a lot recently [7]. The definition of the term 'information model' is as follows [4]: abstraction and representation of the entities in a managed environment, their properties, attributes, constraints, rules, and operations, and the way that they relate to each other. Note that the information model is independent of any specific repository, usage of software aspects, communication protocol, or software platform.

In the standards for information model there have been the DMTF (Distributed Management Task Force) Common Information Model [8] and the IEC(International Electrotechnical Commission) Common Information Model (CIM)[9] used in electric power

transmission and distribution. The former is an information model that is used to unify and extend the existing management standards such as SNMP and CMIP using object-oriented model in computer systems. The latter use a UML (Unified Modelling Language) model, allows application software to exchange information about an electrical network, and can be used to derive design artifacts such as XML Schema for the integration of application software.

In CD 22166-201[4], a common information model (CIM) that can be commonly applied to all modules is being developed. CD 22166-201 presents information that should be used in a common information model based on UML, which is designed based on ISO 2166-1. NP 22166-202 and - 203 are in the NP stage, and will provide an information model for software modules and an information model for hardware, respectively. These two information models are defined by inheriting the common information model.

Common information was based and modified from ISO22166-1 as shown in Table 1. In Table 1, 'M' and 'O' denotes mandatory and optional, respectively. The common information model is shown in Figure 1, which is illustrated in UML.

'Module Name' is the name representing the module. 'Description' provides the overview of the module, what the module is, what it does, and how it can be used. 'Manufactures' provides contact information for designer, developer, manufacturer of the module. 'Examples' provides typical use cases of the module. These 4 items are attributes of class CIM shown in Figure 1.

'Information model version' is the version number of information model. 'Module ID' is the unique identifier of the module within a robot. 'Hardware Aspects' and 'Software Aspects' are related only to composite modules. If the module is composed of two or more hardware-software modules, software modules, and/or hardware modules, their module IDs are listed in the Hardware aspects and the Software Aspects, respectively. These 4 items are attributes of class IDnType shown in Figure 1, which is one of the classes that compose of CIM.

'Module properties' are values that are generally used in initialization of modules. Module properties are classified into mandatory and optional ones. This information is stored into class Properties in Figure 1.

'Inputs/Outputs' describes names of variables for data transfer into and/or from a module, whose information is stored into class IOVariables in Figure 1. The usage of this information is similar to ROS Topics used in publish or subscribe mode.

'Status' describes a status of a module that is operating, whose information is stored into class Status in Figure 1.

'Services(capabilities)' describes information for interfaces that a module provides and utilizes for robot services, which is stored into class Services in Figure 1. The related information is the prototype of a function or method, which consists of function name, data type and name of arguments, and return type. The class Services can compose of one or more method groups, which have one or more methods.

'Infrastructure' lists hardware and/or software that the modules commonly uses or connects to, whose information is stored into class Infrastructure in Figure 1. Examples of the information are database type, mechanical framework, power type, and middleware type such as ROS, openRTM, and OPRoS.

'Safety/Security' describes the safety-related performance level and the security information provided by the module, whose information is stored into class SafeSecure in Figure 1. The safety-related information is provided as SIL(safety integrity level) IEC62061 or PL(performance level) ISO 13849-1 and the security levels 1~4 are defined in IEC 62443-4-2. If a module has several safety functions, the module provides a overall PL or SIL of the module using the combination of the performance levels of the several safety functions of the module or via the verification and validation of the module's overall safety-related function.

Table 1. Common information for modules and the corresponding class

| NO.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | ITEMS                     | Common Information Model 2) | Information models for modules 3) |                 |                 | Corresponding class |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------|-----------------------------|-----------------------------------|-----------------|-----------------|---------------------|
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                           |                             | hardware-software module          | hardware module | software module |                     |
| 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Module Name               | M                           | M                                 | M               | M               | CIM                 |
| 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Description               | M                           | O                                 | O               | O               |                     |
| 3                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Manufactures              | M                           | M                                 | M               | M               |                     |
| 4                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Examples                  | M                           | O                                 | O               | O               |                     |
| 5                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Information model version | M                           | M                                 | M               | M               | IDnType             |
| 6                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Module ID                 | M                           | M                                 | M               | M               |                     |
| 7                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Hardware Aspects          | M                           | M                                 | M               | -               |                     |
| 8                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Software Aspects          | M                           | M                                 | -               | M               |                     |
| 9                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Module properties 1)      | M                           | M                                 | M               | M               | Properties          |
| 10                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Inputs                    | M                           | O                                 | O               | O               | IOVariables         |
| 11                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Outputs                   | M                           | O                                 | O               | O               |                     |
| 12                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Status                    | M                           | O                                 | O               | M               | -                   |
| 13                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Services(capabilities)    | M                           | M                                 | M               | M               | Services            |
| 14                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Infrastructure            | M                           | M                                 | M               | M               | Infra               |
| 15                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Safety/security           | M                           | M                                 | M               | M               | SafeSecure          |
| 16                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Modelling                 | M                           | O                                 | O               | O               | Modelling           |
| 17                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | ExecutableForm            | M                           | O                                 | O               | M               | ExecutableForm      |
| 1) It is mandatory only to those who can be influenced (set) from the outside or at least to those, which have an expected effect on other modules.<br>2) All kind of items for CIM are mandatory.<br>3) For information models such as hardware-software module, hardware module, and software module, some types of items can be omitted depending on their functionalities. In particular, for information models of hardware module and software module, the items “software aspects” and “hardware aspects” are not included, respectively. |                           |                             |                                   |                 |                 |                     |

‘Modelling’ provides different kinds of models for simulation and/or design purpose, whose information is stored into class Modelling in Figure 1. Paths of 3D graphic files used in simulation are stored into the class.

‘ExecutableForm’ provides program codes executed to achieve or support the module’s purpose, whose information is stored into class ExecutableForm in Figure 1. Paths for executable files in binary and source files in python are stored into the class. Note that the former is the compiled code and the latter is the source code, which utilize the interpreter.

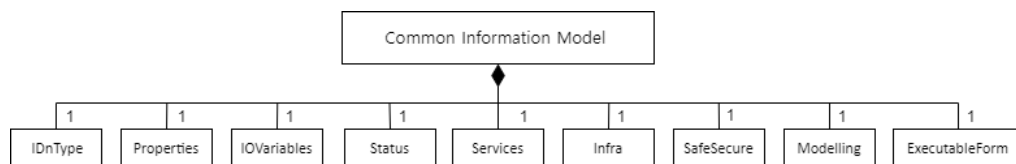


Figure 1. Class diagram of common information model

Figure 2 is the detailed class diagram for common information model, which is extended version of Figure 1 and shows the detailed attributes of classes consisting of common information model.

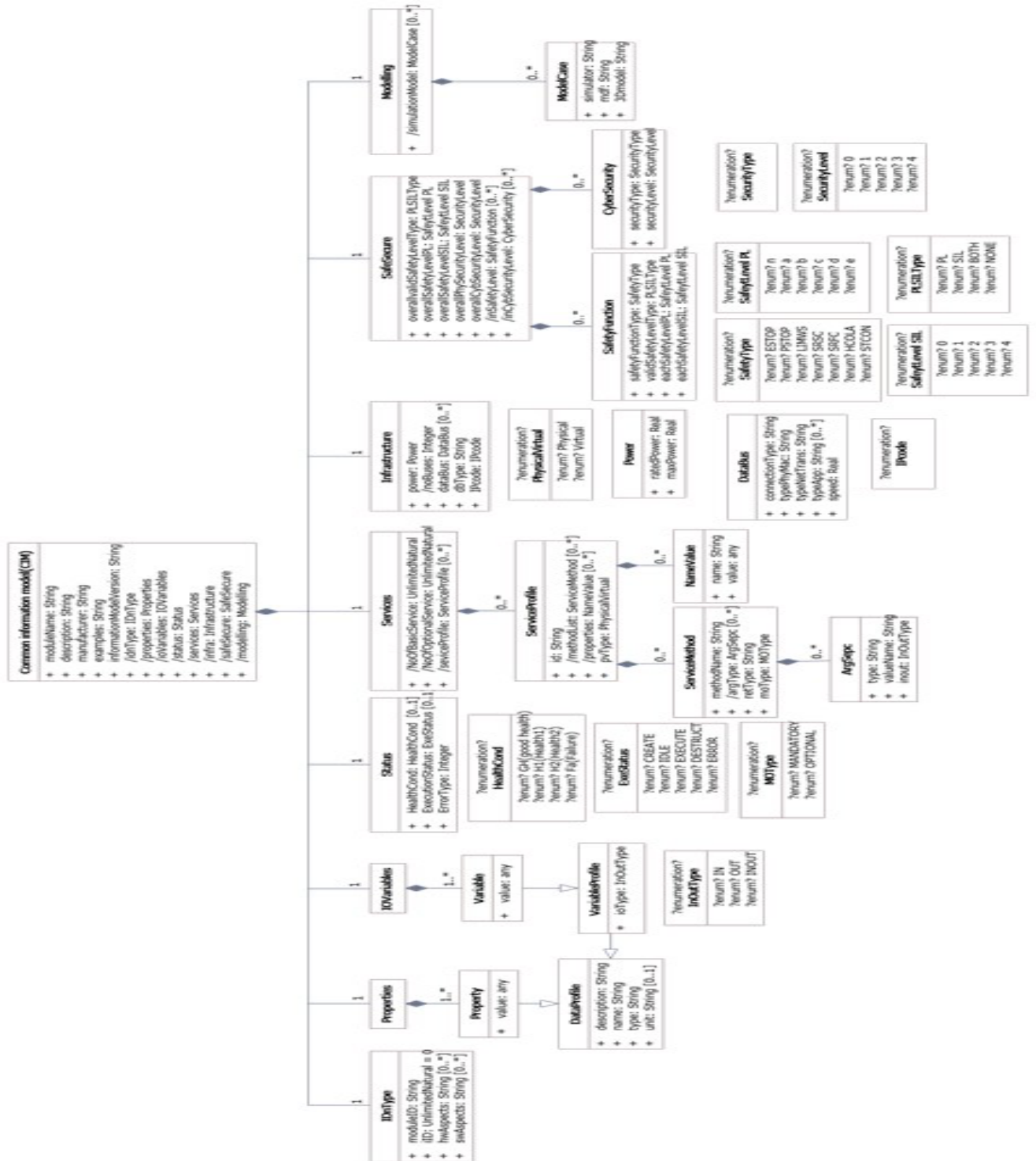


Figure 2. Detailed class diagram of common information model

This paper introduced common information for modules and the common information model, which can apply to hardware modules and software modules used in robot systems and is developing as international standards in ISO TC299 WG6.

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