




# A Methodological Assistant for Use Case Diagrams

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**Abstract:** Use case driven analysis is the corner stone of software and systems modeling in UML and SysML, respectively. Although many books and tutorials have discussed the use of use case diagrams, students and industry practitioners regularly face methodological problems in writing good use cases. This paper defines a methodological assistant that helps designing use case diagrams relying on formalized rules and reuse of previous diagrams. The methodological assistant is implemented in Python. It is interfaced with the free SysML software TTool, and with Cameo Systems Modeler.

## 1 INTRODUCTION

Adoption of Model-Based Systems Engineering approaches is a challenging issue for systems and software manufacturers. Implementing a MBSE approach requires working on a triptych (language, tools, method). Ranging from formal methods to diagrammatic notations such as UML (OMG, 2018) and SysML (OMG, 2017), many papers have discussed model simulators, formal verification tools, and code generators. By contrast, little work has been published on tools that may assist UML and SysML diagrams designers in implementing a method.

This paper discusses the use of UML and SysML use case diagrams, and good ways of developing them using a methodological assistant. Two complementary avenues are explored. First, the assistant can help constructing use case diagrams relying on formalized rules and repositories of previously designed use case diagrams. Second, the assistant can check use case diagrams a posteriori.

The paper is organized as follows. Section 2 identifies difficulties in writing good use case diagrams. Section 3 discusses the design and implementation of UCcheck, a methodological assistant that is coded in Python and interfaced with TTool (TTool, 2019) and Cameo Systems Modeler (Casse, 2018). Section 4 discusses a case study. Section 5 surveys related

work. Section 6 concludes the paper and outlines future work.

## 2 GUIDELINES FOR DRAWING USE CASE DIAGRAMS


### 2.1 Use Case diagrams


A SysML (resp. UML) use case diagram identifies the main functions and services to be offered by a system (resp. a piece of software).


A rectangle defines the boundary of the system or software, and names it (On Figure 1 the system is named *Real-Time System*). The ovals depict the use cases that contain the names of the functions or services to be offered. On Figure 1, *Perform Computation* is a use case.

A use case diagram defines relations between pairs of use cases. On Figure 1, the extend relation makes *InformUsers* and *StoreResults* an option of *PerformComputation*. The include relation from *PerformComputation* to *AcquireInputs* states each computation demands to acquire values from sensors.

A use case diagram also shows the system or software interacts with its environment, the latter being depicted by a set of actors. On Figure 1, a link connects use case *AcquireInputs* to actor *Sensors*.

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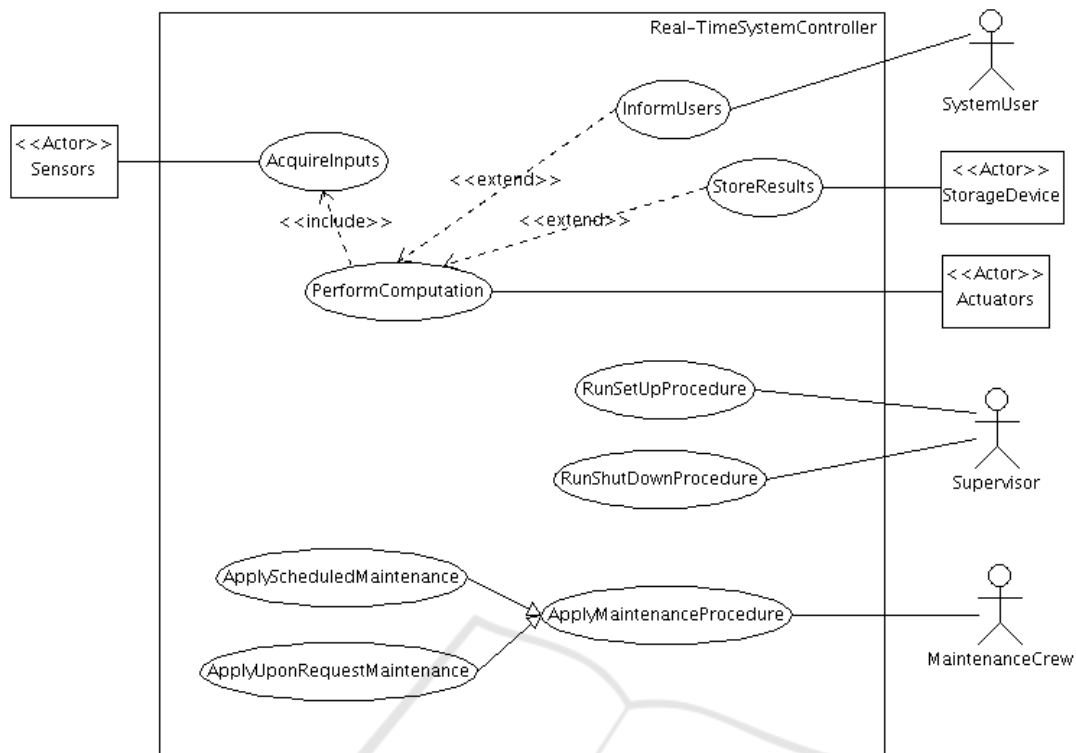


Figure 1: Use Case Diagram for real-time systems.

## 2.2 Generic Use Case Diagram

To create a generic use case diagram for a large variety of systems, one needs to keep in mind that:

- A system has a nominal behavior.
- A system may enter downgraded modes.
- A system must run a set up procedure before starting its execution.
- A system must run a shutdown procedure before being moved or updated, and more generally maintained and serviced.
- Maintenance is a normal concern when one is designing a system.

Relying on previous principles, Figure 1 depicts a generic use case diagram for a real-time system controller that receives inputs from sensors and triggers output devices, part of the latter being in charge of informing the user and the supervisor of the system.

The use case diagram in Figure 1 depicts the set-up, shutdown and maintenance phases that are usually concealed by the use case diagrams presented in paper or books addressing real-time systems modeling. One may note that Figure 1 does not mention degraded modes: they will be addressed in sequence or activity diagrams associated with the use case diagrams.

These documentation-purpose sequence and activity diagrams are not presented in this paper. Discussion is limited on use case diagrams for themselves.

## 2.3 Difficulties for Beginners

SysML textbooks and tutorials usually recommend a four-step process to create a use case diagram: (1) define the boundary of the system; (2) identify the actors as external entities that interact with the system; (3) identify the use cases from the actors' goals; (4) establish the connections between actors and use cases, and set up relations between pairs of use cases. This methodology is usually explained through an example for a simple system (Weilkiens, 2011).

However, a major difficulty among beginners is to maintain the use cases at the right level and to not confuse between high-level functions and elementary actions. The structure of the use case diagram induces functional decomposition and consequent insertion of low-level functions that do not generate value for the actors (Holt and Perry, 2008).

With experience, the identification of use cases becomes easier as the designer can rely on past models. Thus, one way to help beginners is to provide various examples of use case diagrams. However, the number of examples needed to cover multiple do-

mains may be very large. A better solution is to provide generic diagrams, which can be adapted to similar systems. These diagrams can be designed by experts based on experience, and then be provided to beginners to serve as guides. Consequently, an assistant for use case diagrams should manage a repository of example diagrams, helping to retrieve and customize them.

Other common beginners' errors have been investigated in the literature. The studies were conducted with students and identified difficulties with choosing the right type of relationship, defining the direction of the `extend` relationship and proper naming of elements (Kruus et al., 2014a) (Chren et al., 2019a) (Holt and Perry, 2008). For example, they reported the absence of verbs in use case names and the use of proper names for actors rather than a common name representing a role. Consequently, an assistant for use case diagrams should not only guide the identification of actors and use cases, but also verify the diagram compliance with SysML/UML and systems engineering guidelines.

### 3 METHODOLOGICAL ASSISTANT

#### 3.1 Overview

In order to help designing use case diagrams, two forms of assistance can be proposed: a priori assistance, to facilitate the creation of a correct diagram from scratch; and a posteriori assistance, to increase quality and correctness of a semi-finished diagram. The methodological assistant discussed in this paper offers the two forms of assistance. The first version of the tool merely verified whether a diagram is compliant with SysML and Systems Engineering guidelines or not. This was insufficient to help beginners, who find it difficult to select elements (actors and use cases) at a good level of abstraction. The tool was enhanced to guide the creation of a new diagram from a reference one. An additional module was developed to store the reference use case diagrams in a database.

The methodological assistant is developed using Python and the `Tkinter` library for user interfaces. The rest of this section overviews the main modules of the tool, the use of which will be illustrated in Section 4.

#### 3.2 Verification Module

The *Verification* module receives a use case diagram in XML format, identifies its elements and verifies

them against SysML rules and guidelines. The module accepts XML files generated by two modeling tools: TTool (TTool, 2019), a free software developed by Telecom Paris, and CAMEO Systems Modeler (Casse, 2018), a tool developed by NoMagix, now a subsidiary of Dassault Systèmes.

A first step of the analysis consists of transforming the XML file to a common object-oriented structure. In this structure, the diagram is a class that possess components and connectors. Components have as attributes: name, type and position in the diagram. Connectors, on the other hand, have name, position and a reference to each one of two components being linked. The objective of this pre-processing step is to gain independence from the modelling tool. Then, to extend the assistant to a new SysML/UML tool, one need only to write a program that extracts the elements and stores them in the class structure.

A set of rules, not listed here for space reasons, has been established (Rizzo Aquino, 2019). Part of these rules can be verified automatically. Others require user confirmation about the compliance with the rules.

Two Python libraries were important for the verification module: `wordnet` to identify the grammatical class of actors' and use cases' names, and `networkx` to verify some relationship properties after transforming the diagram into a graph.

#### 3.3 Import Module

The *Import* module accepts a use case diagram in XML format from TTool or CAMEO Systems Modeler and stores it into a database.

A graphical interface asks the user whether the inserted file is a reference or an example one. A reference is defined as a general diagram for a group of similar systems and can be used to guide the conception of new diagrams. An example is a diagram for a specific system, which must be associated with the name of a general category.

Using a database structure allows one to represent the diagrams independently of the SysML tool. The database model mimics the object-oriented structure explained in 3.2. Moreover, a database stores a large number of diagrams, and the execution of complex queries.

#### 3.4 Creation Module

The *Creation* module guides the user on the identification of actors, use cases and relationships based on a reference diagram chosen from the database. Then,

a graph is drawn to display elements and connections identified in the diagram.

At each design step, the program suggests improvements. For example, if two actors are associated with the same use cases, the program asks whether they cannot be grouped into one common general actor.

## 4 CASE STUDY

### 4.1 A Priori Assistance

To demonstrate the functionalities and benefits of the verification module, this section uses an agricultural drone. The first version of the use case diagram (Figure 2) contains purpose-made errors that will be identified by the assistant.

According to the use case diagram, the system possess two main functions: “control drone” and “spread pesticides”. Actor `Buyer` is interested in the two main functions. Actor `Farmer` is interested in pesticide application. Actor `operator` is responsible for controlling the drone. An actor named `Customer` can be seen isolated in the diagram.

The interface of the verification assistant is divided into tabs, each tab for one group of rules. (Figure 3) shows the tabs. The first one overviews the use case diagram and the points to be verified. A checklist helps clarifying the step-by-step verification process and quickly localizing the mistake(s). Additionally, the program helps the user to improve the level of abstraction of the diagram. Having more than 20 (Balzert, 2006) use-cases may indicate the presence of too low-level functions.

The next two tabs are focused on actors and use cases. The program automatically verifies rules such as “Names must start with a capital letter, be unique and belong to correct grammar class.” The actors should be named by common nouns. Use cases should start with a verb. Also, the program looks for use cases and actors that remain isolated.

The semantic compliance checks whether the actors and the use-cases respectively represent external roles and high-level functions that produce an observable result to an actor.

Note that verifying string equality is not sufficient to assure uniqueness of actor’s names. Therefore, the Leacock-Chodorow similarity function of Python’s library `wordnet` is used to certify that all names are semantically different.

For our case study, it was possible to identify syntactical errors. For instance, actor `operator` does not start with a capital letter. Further, actor `Adjustment`

in strong wind must be rephrased with the verb `Adjust`. The program also pointed out that the actor `Customer` is isolated in the diagram. Through the semantic analysis mentioned above, a high correlation is identified between the names `Customer` and `Buyer`. Thus, one could hypothesize that the user changed the name of actor from `Customer` to `Buyer` but forgot to delete the old one. In this case, the correction will be to remove the isolated actor from the diagram. However, in other situations, the problem may be a relationship that is missing.

Besides, through answering the questions, the user noticed some incorrect use cases: `Control valves` was too low-level and could be removed, and `Control drone` was in the point of view of the user and should be rewritten as the real function performed by the drone, which is “Change direction by remote control”. An extract of the actors check tab is provided by Figure 3. The use cases check tab follows the same structure.

Then, the assistant checks the correctness of the relationships between elements of the use case diagram. Similarly, it is possible to automatically verify some basic properties, such as no double linkage between the same pair of elements, no cycles, and correct type of elements for each type of relationship (for example, an association can only be defined between one actors and one use case). These checks guarantee no relationship was left unintentionally.

For our case study, it was identified the incorrect use of an association to link two use cases. This relation needs to be changed to either an “include”, an “extend” or a “generalization” relation - the only possibilities between use cases. The correction applied by the user is to change the association to a include relationship. Further verification of relationships is only possible if all the above properties are respected. The user has to apply the corrections mentioned until then and resubmit an intermediate version of the diagram.

The correctness of the basic properties allows the user to verify whether the type of relationships between use cases agrees with the desired meaning. Asking the user if it is a necessary, an optional or a specialization relation accomplishes this. These ideas should correspond to the “include”, “extend” and “generalization” relationship, respectively. A warning message is exhibited in case of mismatch. The user is also asked if the relation is in the correct direction or not. Only with the use case diagram, it is not possible to verify automatically if relationships are consistent with their meaning. Therefore, the check is user dependent. The advantage of the designed interface is that it does not directly use the SysML/UML

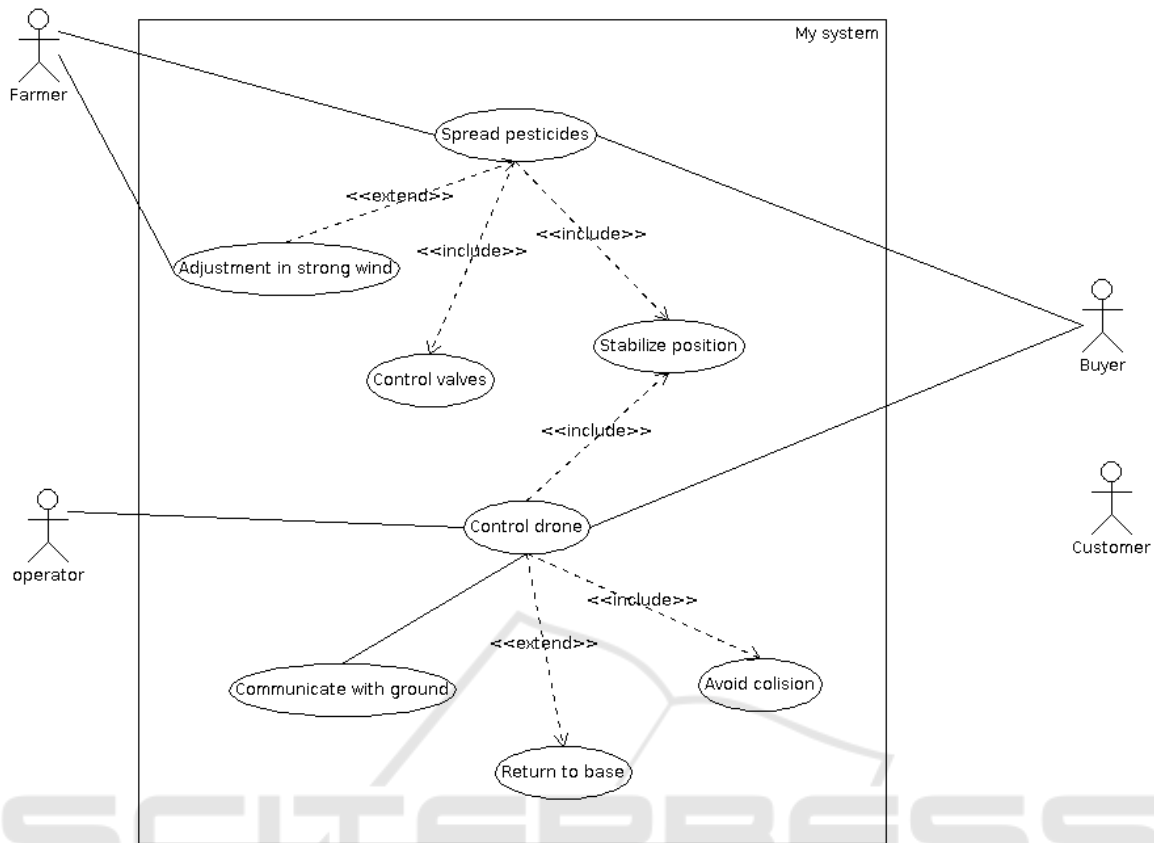


Figure 2: Initial use case diagram for an agricultural drone.

General	Actor	Use case	Relationship	Layout	Coherence	
Actors	Uppercase	Unique	Noun	Not isolated	Is it a role?	Is it external to the system?
Customer	✓	✓	✓	✗	✓	✓
Buyer	✓	✓	✓	✓	✓	✓
Farmer	✓	✓	✓	✓	✓	✓
operator	✗	✓	✓	✓	✓	✓
Check correlation			Confirm options		Confirm options	

Figure 3: Extract of Actor Tab for verifying the name and meaning of the actors.

nomenclature, which poses problems for beginners. Instead, it uses the idea behind the relationship type, which is less prone to confusion and helps to reinforce nomenclature learning. The interface designed to verify the points mentioned above is portrayed in Figure 4.

For the diagram in Figure 2, the user of the methodological assistant identified two reverse relations, and one incorrect meaning. He noticed that the use case *Return to base* should be rewritten to represent an action performed only in case of bad weather conditions. With the right set of questions, the assistant reinforces inspection on commonly misunderstood points.

Furthermore, the tool contributes for a cleaner di-

agram by identifying unnecessary relations. For example, an actor associated to a use case does not need to be associated to its refined use cases, since there is already an implicit communication. Similarly, a specialized actor implicit communicates with the use cases linked to the generalized actor. No unnecessary relationship was found in our case study.

Finally, by analyzing relationships, the assistant can identify those actors and use cases that are possibly of too high-level, in the case they are connected to all elements. It can also identify actors that may represent the same role in the case they are associated to the same set of use cases.

The assistant identifies that actor *Buyer* is a too high-level one. This means that either the diagram



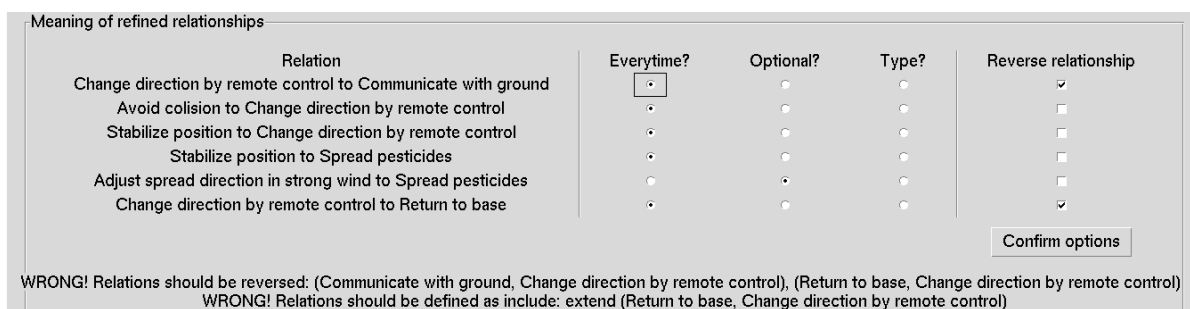


Figure 4: Extract of *Relationships* Tab for verifying connection properties.

conveys the point of view of *Buyer* and the latter does not need to appear, or that *Buyer* represents multiple roles and should be decomposed, or that some use case is missing. For the case study, a decomposition of actor *Buyer* leads to actors that are either similar to *Farmer* or to *Operator*, in the sense that they would be connected to the same set of use cases. Thus, the user finds out that actor *Buyer* actually combines the two roles already in the diagram and can be taken out of it. In other words, one can say that the diagram is represented from the buyer’s point of view.

The two remaining tabs are focused on points not directly related to actors, use cases and relationships. The layout tab checks for the presence of a border. It also verifies whether the actors were positioned according to the categorization into primary actors whose goal is fulfilled by the system, and secondary actors who support the system. Although the classification into primary or secondary actors is not a language standard, it is a common guideline among SysML/UML community that should be followed for interpretation purposes.

The coherence tab certifies that each use case is documented by at least one scenario. This is accomplished by asking the user to match the use case to the corresponding documentation, which can be a textual description, a sequence diagram or an activity diagram. Additionally, the matching must be coherent with the relations between pairs of use cases. For example, an included use case should appear in all the scenarios of the including use case, because there is a necessary relation between the two. On the other hand, an extended use case should only appear in some specific scenarios. Together, these checks reinforce the completeness of the model and the meaning of the relationships between use cases.

In summary, the case study demonstrated the assistant’s ability to improve the diagram. The syntactical errors were corrected, and the unnecessary relationships were eliminated. The meanings of the actors, use case and relationships were reinforced through the questions answered by the user of the

tool. The two patterns (one element related to all the others, and actors associated to the same use cases) contributed to identify possible missing elements. Finally, the coherence matching helped to check whether each use case was documented in a scenario expressed by a sequence diagram.

However, one limitation of the verification module is the dependence on user’s inputs, which may be incorrect. Further work should explore how to automate the user dependent check. One idea would be to use information from other diagrams of the model of the system. For example, the context diagram could be used to verify whether an actor is an external entity to the system, or not. The sequence diagram together with scenario matching could be used to verify the association between actors and user cases.

## 4.2 A Posteriori Assistance

The functionalities of the creation assistant and its potential benefits for beginners will be demonstrated through a case study for a mobile phone camera. This system belongs to the group of real-time systems, whose generic use case diagram is presented in Section 2.2.

The first step in the creation module consists of filling up basic information about the model (author, date and system’s name) and selecting the use case diagram to use as reference. The process requires the reference diagram to be previously inserted into the database. In order to guide the user, the interface presents the name of all example systems stored in the database that are associated with the generic group.

Th user then proceeds to actor identification using the interface presented in Figure 5. A list of suggestions is given based on the reference diagram. For each suggested actor, the user can identify one or more actors of the specific system being modeled. For example, for a cellphone camera, the touch screen corresponds to the sensor that receives capture order and triggers the “Take photograph” functionality. This function is executed by the cellphone camera

module itself, which corresponds to the actuator. The given name must start with a capital letter, be unique and contain a common noun.

For our case study, we identified two possible storage devices: the cellphone internal memory and an external memory. The system user plays the role of taking and visualizing the photo and will be called *Photographer*. The supervisor performs the role of starting and closing the application and will be identified as the *Cellphone Owner*. Often, these actors correspond to the same person in the physical world. Additionally, no maintenance actor was selected, since the part of the system being conceived will not comprise maintenance functions.

Having a list of suggestions from a reference diagram facilitates actor identification, by transforming it to an analogy exercise, and helps to keep the diagram in an adequate level of abstraction. By combining a verification procedure, the assistant guarantees the syntactic correctness of actors' names.

Then, the user proceeds to use case identification. The process is similar to that used for actors, except that each suggestion only derives one use case. For each suggested use case, the user must choose whether or not to add it to the diagram, and by what name. The name must start with capital letter, be unique and start with a verb.

The suggestion list is optimized based on the actors selected. Only use cases that communicate to at least one selected actor are suggested to the user. In our case study, since no maintenance actor was chosen, the use cases related to maintenance will not be suggested to the user.

Finally, the user must establish the connections between the chosen elements. Three tables are depicted in the interface: the first one for relations between actors, the second one for relations between use cases, and the third one for associations between actors and use cases.

These tables are automatically semi-filled based on the reference diagram. The user must input additional relations and make necessary changes. For example, functions that are optional for some real-time systems may be systematically executed in particular ones. Then, the user has to manually change from "extend" to "include" relationship. For a cellphone camera, the use case *Show image* for the photographer when taking a photo will always happen, even if for other types of camera it may be optional.

The advantage of the assistant is to combine orientation from the pattern with a verification procedure. For each new relationship, a series of functions prevent the appearance of cycles, multiple inheritance and unnecessary relationships, as explained in Sec-

tion 4.1.

The use case diagram created is displayed in a graph format, where blue nodes represent actors, red nodes represent use cases, and relationships are given by edges. A list of warnings may be presented to indicate the presence of isolated elements, too-high level elements, that is, connected to all the others, or actors that could represent the same role. Figure 6 exhibits the use case diagram representation generated by the assistant for the case study.

The benefits provided by the creation assistance are an easier process of actors and use cases identification, since it is replaced by an analogical reasoning based on a reference diagram; and a final model more in accordance with UML/SysML rules, as verification procedures are automatically performed when possible.

One drawback of the implemented procedure lies in the necessity to work with a generic diagram, which introduces some dependence on the work of an expert who created the generic diagram. How to obtain generic diagrams automatically from a series of example diagrams for a group of systems is still an open issue.

At the moment, it is not possible to export the graph representation of the use case diagram to a modelling tool because of the positioning problem. An automatic positioning function was used to obtain the most readable graph. However, the arrangement made does not comply with SysML/UML standards. The automatic layout of use case diagrams is a complex problem addressed by some studies (Eichelberger, 2008).

## 5 RELATED WORK

### 5.1 Verifying Use Case Diagrams

Several studies have been conducted on verification of UML/SysML diagrams. Unfortunately, research has tended to focus on analysis of scenarios rather than of use case diagrams. Scenarios can be either modeled by sequence or activity diagrams, or documented by a textual explanation of the use case. Analysis techniques include graph transformation (Zhao and Duan, 2009) (Klimek and Szwed, 2010), logical verification (Klimek and Szwed, 2010) and grammar formalization (Chanda et al., 2009) (Christiansen et al., 2007).

In (Zhao and Duan, 2009) and (Klimek and Szwed, 2010), the authors focused on verifying the correctness and completeness of a scenario, but they did not address a syntactical verification of UML standards. On the other hand, Chanda (Chanda et al.,

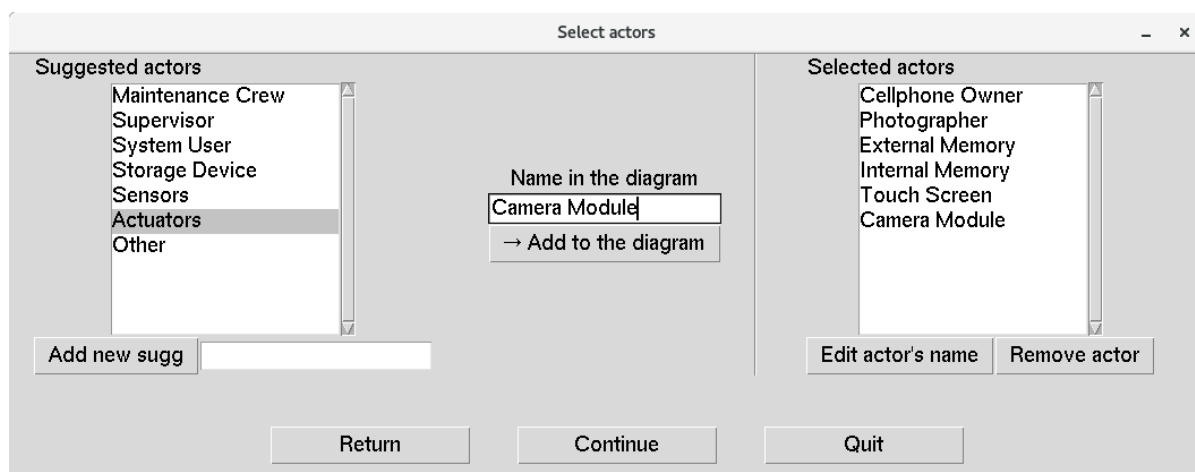


Figure 5: Selecting actors relying on a generic diagram.

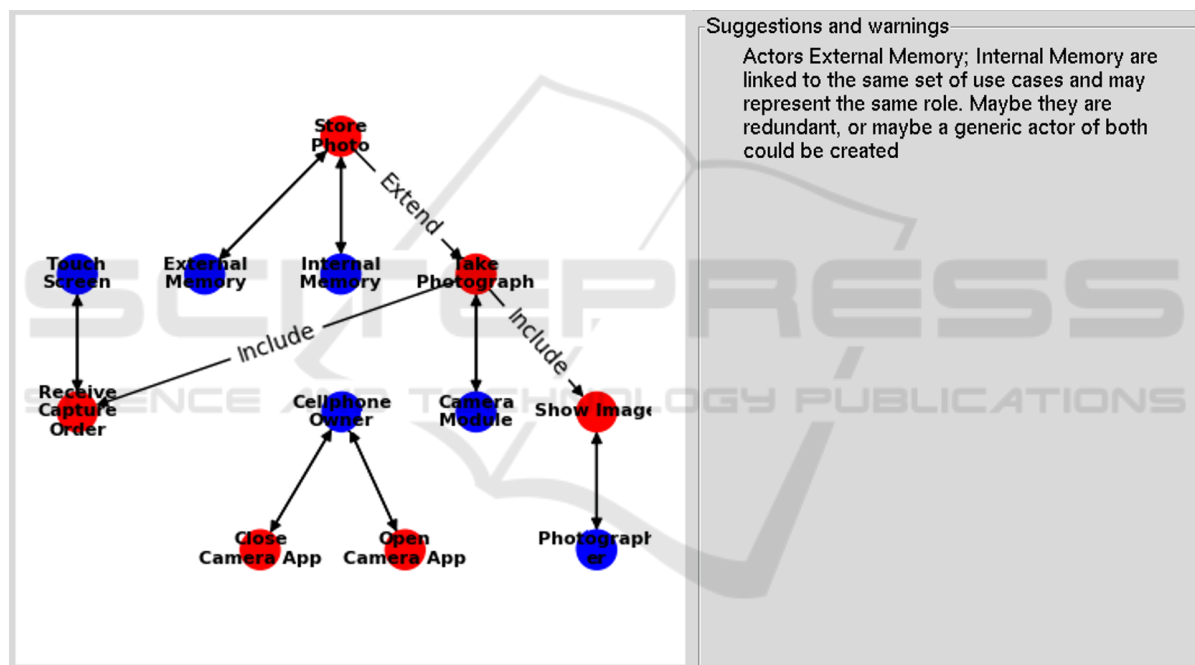


Figure 6: Graph representation of the use case diagram created through the assistance for the cellphone camera. Suggestions for improvements and warnings of missing elements are displayed next to the graph.

2009) investigated the use of formalization to verify syntactical rules, however no computational tool is proposed. The study in (Christiansen et al., 2007) complements the prior by proposing the use of natural language techniques to transform a use case description in the formal model. Deep natural language analysis is not necessary for the proposed assistant, since it works with use case diagrams, in which phrases are simpler and follow a structure - for example, to identify the verb of a use case, extracting the first word of the sentence should be enough.

Some modeling tools have incorporated basic

checks for use case diagrams. For example, verification of double relationships and of repeated elements is available in Cameo System Modeler. The assistant discussed in this paper is different from Cameo by the broader spectrum of points to be verified, and by the dialogue with the user of the assistant, asking him or her questions such as “Is this actor really an external entity?”



## 5.2 Assistance for Use Case Diagram Creation

Many attempts have been made on how to automate the creation of use case diagrams. Certain studies proposed its derivation from other textual documents through natural language processing. The transformation process has been applied to requirement (Seresht and Ormandjieva, 2008), use case descriptions (El-Attar and Miller, 2008) and user stories (Elallaoui et al., 2018). The drawback of these proposals is that the quality of the use case diagram highly depends on the quality of the textual documents. Additionally, in a system engineering logic, these documents are supposed to be conceived from the use case diagram, and not the opposite.

Other studies proposed the reuse of previous diagrams using case base reasoning (CBR) (Srisura and Daengdej, 2010) or ontology (Bonilla-Morales et al., 2012) approaches. From an initial draft of a use case diagram, it was possible to retrieve the most similar diagram from a database. However, the authors did not investigate how to use this approach to create diagrams for new systems.

Finally, some authors examined the problem of UML design from the educational point of view. The studies (Chren et al., 2019b) and (Kruus et al., 2014b) had pointed out the common mistakes made by students in SysML/UML courses. In (Ramollari and Dranidis, 2007), Ramollari proposed an object-oriented modelling tool suitable for students. The tool, called StudentUML, includes design and verification of some UML diagrams, as the sequence and class diagram. Particularly, the use case diagram is not addressed. Verification is only available for diagrams drawn in the platform. With respect to creation, the assistant proposed in this article differs from Ramollari's tool by the guidance functionality that is provided to beginners. Actually, StudentUML works like other modelling tools, but it offers a simpler interface and further verifications.

## 6 CONCLUSIONS

A MBSE approach relies on a triptych (language, tool, method). In terms of language, this paper focuses on use case diagrams and more precisely on the version of them supported by the OMG-based languages UML and SysML. In terms of tool and method, the authors of this paper make a 3-fold statement: (1) use-case diagrams have been existing for many years ; (2) their use is the cornerstone of the use case driven analysis step of the methods associated

with UML and SysML, and (3) Nevertheless, many people still have difficulties in writing good use cases.

Previous three statements provide the rationale behind the design and prototyping of a methodological assistant that help UML and SysML model designers to create and review their use case diagrams. The tool named UCcheck helps constructing use case diagrams relying on formalized rules and repositories of previously designed use case diagrams. It also check use case diagrams a posteriori and suggests improvements.

UCcheck is a free software coded in Python. UCcheck was first interfaced with TTool, the free software from Telecom Paris that we used to draw the use case diagrams in Figure 1 and Figure 2. TTool has further been applied for teaching, enhancing the expression power of SysML (de Saqui-Sannes and Aprville, 2016), and for tooling the first steps of the life cycle of systems (de Saqui-Sannes et al., 2018) (Mattei et al., 2017) (Daigmorte et al., 2019).

The use of UCcheck is not restricted to TTool. Indeed, UCcheck stores use case diagrams using an intermediate form that is not specific to one particular UML or SysML tool. An interface exists for Cameo Systems Modeler, a commercial tool from Dassault Systems. Similarly, UCcheck can be interfaced with other SysML tools such as Enterprise Architect (SparkSystems, 2019) and Rhapsody (IBM-Rhapsody, 2019).

Beyond its interfaces with SysML tools, UCcheck can be extended in several directions. In terms of language, the tool may evolve if SysML2 (Object-Management-Group, 2017) modifies the syntax or semantics of use case diagrams. In terms of assistance technique, introduction of Case Base Reasoning (CBR) may contribute to reuse SysML models or patterns to assist the designer of use case diagrams.

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