Do We Need Specific Quality Models for Multi-Agent Systems?
Toward Using the ISO/IEC 25010 Quality Model for MAS

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Abstract: The quality assurance of software is one of the most important purposes of software engineering. However, the quality concept is undergone to subjective interpretations. Consequently, several models are proposed to understand and evaluate the software quality. The ISO/IEC 25010 is the new international standard quality model. Being standard increases the applicability of such model for all software products. Knowing that the multi-agent systems are one of the most applied software paradigms; we target in this paper the applicability of the ISO/IEC 25010 to agent-based software.

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1 INTRODUCTION

The *quality* is one of the most required goals in software engineering. This concept encompasses several software characteristics which can be sometimes conflicting (ISO/IEC, 2001). Moreover, it is undergone to subjective interpretations. Thus, several models are proposed to unambiguously specify and objectively measure the software quality. Furthermore, some standards are proposed by the ISO (ISO/IEC, 2001; ISO/IEC, 2011).

Nowadays, the software engineering domain is characterized by the diversity of the software paradigms with owned specificities which require their specific development approaches. Specifically, each software paradigm needs its specific quality model. Previously, the efforts were devoted to develop quality models for specific software paradigms (Alonso et *al.,* 1998). However, customizing the standard quality models to support the specificities of each paradigm is the purpose of the recent research works (Behkamal, Kahani and Akbari*,* 2009; Lew, Olsina and Zhang, 2010).

Knowing that the multi-agent systems (MAS) are one of the most applied software paradigms nowadays; this work in progress targets the quality of agent-based software. Specifically, we study in this paper the ability to apply an international standard quality model, called ISO/IEC 25010 (ISO/IEC, 2011), to MAS. Considering the almost proposed studies in this field as empirical ones (Dumke et *al.*, 2010) is our main motivation. Despite that Alonso et *al.,* attempt through a set of works (Alonso et *al.,* 2008; Alonso et *al.,* 2009; Alonso et *al.,* 2010) to develop a specific quality model for MAS; we believe that these studies should be preceded by the study of the ability to apply the standard quality models to such systems. It seems obvious that the use of standard quality models, when it is possible, is more beneficial than the use of specific ones.

In order to reach our goal, we start by identifying the main features of the MAS. The identified concepts are studied comparing to the sub-characteristics of the ISO/IEC 25010 in order to identify the MAS' concepts which are not specified in such quality model. This latter should be finally extended to support the lacked concepts.

The remainder of this paper is organized as follow. In section 2 we present the multi-agent systems in order to identify the key concepts of such paradigm. We give an overview of the ISO/IEC 25010 in section 3. Section 4 is devoted to present the suggested extensions applied to ISO/IEC 25010 for supporting MAS. Finally, conclusion and some future works are presented in section 5.

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2 MULTI-AGENT SYSTEMS

Multi-agent systems represent a well known software paradigm which allows the modelling and the development of complex systems. Consisted of the intersection of several fields (such as software engineering, distributed systems and artificial intelligence), such paradigm is applied in various application domains ranging from games to space shuttles. The drawback of this variety is reflected in the lack of a consensus about the *agent* definition.

We adopt in this paper the definition of Wooldridge (2009). So, an agent is "*a computer system that is **situated** in some environment, and that is capable of **autonomous** action in this environment in order to meet its design objectives*". Thus, the autonomy is the main property of an agent. However, the intelligent agent can be characterized by some additional properties, such as the ***reactivity***, the ***pro-activeness*** and the ***social ability*** (Wooldridge, 2009). The central concepts of agents are defined as following:

- **Autonomy**: the capacity of the agent to act without the intervention of others. Therefore, an autonomous agent has the control over its internal state and its behaviour.
- **Situatedness**: the ability of the agent to sense and act on its environment. It seems important to note that the environment can either physical or software environment.
- **Reactivity**: the ability of the agent to perceive and to give an adequate response in required time.
- **Pro-activeness**: the ability of the agent to exhibit goal-oriented behaviours.
- **Social ability**: the ability of the agent to interact with other agents in order to achieve its purposes.

Using the agent as the key concept of a MAS, we can define MAS as a set of interacting agents. Figure 1 gives the meta-model of the MAS.

Several reasons encourage us to adopt this definition of the *agent*. Firstly, it is one of the most accepted in the field community. In addition, it remains valid without interesting updates since its first version proposed by Wooldridge and Jennings (1995). Finally, it gives only the essential properties of the agent, called *weak notion of agency*, and allows adding other ones (such as the adaptability and the mobility). So, adopting this *weak* notion increases the applicability and the extensibility of our work.

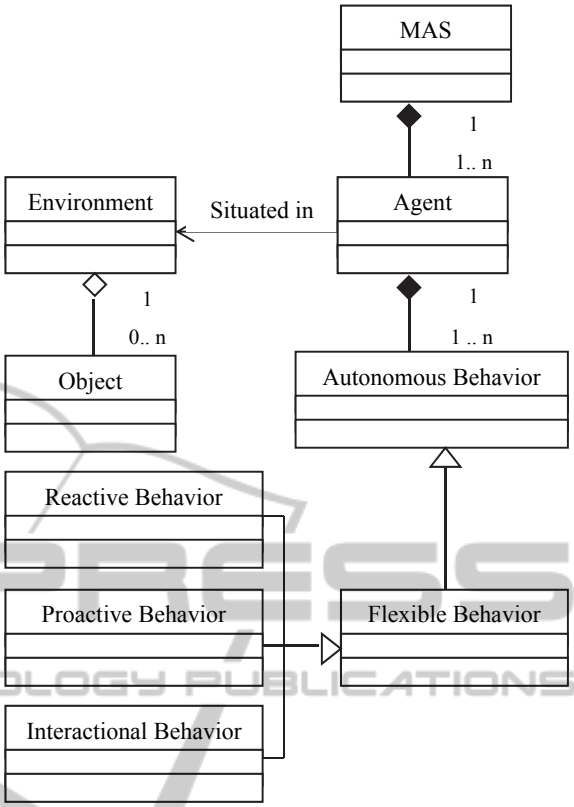

Figure 1: The meta-model of MAS.

In the literature, many works addressed the quality of MAS. However, almost of them are proposed to assess the different aspects related to the agent-based software (Dumke et *al.*, 2010).

Motivated by the lack of specific quality model for MAS, Alonso et *al.* proposed a series of works in order to develop a quality model for this software paradigm (Alonso et *al.,* 2008; Alonso et *al.,* 2009; Alonso et *al.,* 2010). As a first step of this series, they identified the main features of the MAS which consisted of (Alonso et *al.,* 2008): the *social ability,* the *autonomy,* the *pro-activity,* the *reactivity,* the *mobility,* the *intelligence*, and the *adaptability*. Then, they studied separately each feature by decomposing it in a set of attributes. In addition, the attributes can be assessed using proposed metrics. For example, the social ability is decomposed in communication, cooperation and negotiation attributes (Alonso et *al.,* 2008). The autonomy and pro-activity have been studied respectively in (Alonso et *al.,* 2009) and (Alonso et *al.,* 2010).

Despite the importance of the approach proposed by Alonso et *al.,* (2008, 2009 and 2010); we believe that it suffers from several limits. Firstly, the proposed characteristics and their relationships are questionable. For instance, *are the **mobility** and the*

adaptability *fundamental features for* ***any*** *agent*? *What we intend by the* ***intelligence*** *concept*? And *is this latter totally independent from the* ***pro-activity****, the* ***reactivity*** *and the* ***adaptability***? Therefore, the proposed quality model omitted the relationships between the cited agent specific features and the high level software quality characteristics (such as the reliability, the security, the maintainability, etc).

Away from all these issues, the most important asked questions: *Do we really need a* ***specific*** *quality model for MAS in addition to the existing standard ones*? Specifically, *is the ISO/IEC 25010 quality model unsuitable for agent-based software*? *What are the possible updates that must be carry out to this international standard quality model to support the specificities of MAS*? In fact, it is more beneficial to use the standard quality model when possible than the proposition of specific one for each software paradigm. In this paper, we attempt to give answers to the above questions.

3 ISO/IEC 25010 QUALITY MODEL

Since 1970s where the software quality became one of the subjects of software engineering, several quality models are developed. Despite the usefulness of the proposed models, their diversity made confusion (Behkamal, Kahani and Akbari, 2009). Consequently, the international standards are proposed as an answer to this situation.

ISO/IEC 9126 (ISO/IEC, 2001) defined the quality model as "*the set of characteristics and the relationships between them which provide the basis for specifying quality requirements and evaluating quality"*. In fact, this quality model is composed of three layers: characteristics, sub-characteristics and metrics. In the first layer, it specified six characteristics: *the functionality, the reliability, the usability, the efficiency, the maintainability* and *the portability*. Therefore, the second layer is composed of twenty-seven sub-characteristics. Each sub-characteristic can be evaluated using a set of metrics proposed in the third level of this quality model.

Recently, the ISO/IEC 9126 (ISO/IEC, 2001) is improved through the proposition of new international standard quality model, called ISO/IEC 25010 (ISO/IEC, 2011). In fact, the ISO/IEC 25010 is proposed as a part of the SQuaRE series of standards which considered as a new generation of software quality models (Suryn and Abran, 2003). These improvements consisted of adding new characteristics, adding new sub-characteristics, extending the scope of the quality model and renaming some characteristics and sub-characteristics (ISO/IEC, 2011). Consequently, the ISO/IEC 25010 became composed of eight characteristics: *the functional suitability, the reliability, the performance efficiency, the operability, the security, the compatibility, the maintainability* and *the transferability*. Therefore, these characteristics are decomposed on thirty-eight sub-characteristic. The space limit of this paper prevents us to present deeply this quality model.

Both the international standard quality models were applied to specific software products. For examples, the ISO/IEC 9126 standard was updated to support the specificities of the specifications test (Zeiss et *al.,* 2007) and the B2B applications (Behkamal, Kahani and Akbari, 2009). Similarly, the ISO/IEC 25010 was applied to Web applications (Lew, Olsina and Zhang, 2010), quality in use of Web portals (Herrera et *al*., 2010) and to evaluate the performance of cloud computing systems (Bautista, Abran and April, 2012). Generally, the application of the international standard quality models passes through adding some specific characteristics or sub-characteristics. In addition, specific characteristics or sub-characteristics can replace existing ones. For example, Zeiss et *al.* (2007) added the *reusability* and replaced the *functionality* by the *test affectivity* in order to apply the ISO/IEC 9126 to specifications test. On the other side, the sub-characteristics' level has been addressed by adding the *traceability*, *availability*, *customizability* and *navigability* in the case of B2B quality (Behkamal, Kahani and Akbari, 2009).

According to Behkamal, Kahani and Akbari (2009), the variety of quality models is a source of confusion. Thus, the development of specific quality models for a specific software products or paradigms is not supported when the application of the international standard models is suitable. This point of view is justified by the generality which characterizes both ISO/IEC 9126 and ISO/IEC 25010 quality models. The next section is devoted to study the applicability of the ISO/IEC 25010 to MAS.

4 TOWARD APPLYING ISO/IEC 25010 TO MULTI-AGENT SYSTEMS

As we mentioned above, the international standard quality models can be applied to all software products, taking into account the specificities of each one. Consequently, we study in this section the suitability of using the ISO/IEC 25010 to specify the quality of MAS. Moreover, we attempt to propose some extensions to support the specific features of MAS. Compared to the ISO/IEC 9126, the choice of ISO/IEC 25010 is unquestionable because this quality model is a revision of the first one.

In order to reach our purpose, we apply the following steps. First, we identify the essential features of MAS. Then, we check the suitability of these features according to the ISO/IEC 25010 sub-characteristics. As a result, we select the features of MAS which are not specified in this quality model. Finally, we use the selected features to propose an extension of the ISO/IEC 25010 that supports MAS.

As presented in section 2, we choose the definition of the agent proposed by Wooldridge (2009). Hence, the essential characteristics which made of the agent a distinguish software paradigm are: the ***autonomy***, the ***situatedness***, the ***reactivity***, ***pro-activeness*** and the ***social ability***. Based on the weak notion of agency, this list represents the essential features of any agent. Choosing *only* the *essential* features of agents gives two main benefits. It gives an agreed level of consensus for our proposed extension. On the other hand, it allows us to extend the actual work to support some specific kinds of agents (like mobile agent).

Compared to the features presented by Alonso et *al.,* (2008), we have as common ones: the autonomy, the reactivity, the pro-activeness and the social ability. Our list is extended only by the *situatedness* that refers to the MAS environment. This latter is considered as an essential part of any MAS (Wooldridge, 2009; Weyns, Omicini and Odell, 2007; Beydoun et *al.,* 2009). However, Alonso et *al.,* (2008) presented the *mobility*, the *intelligence* and the *adaptability* as required characteristics of agents. We think that these characteristics are not only questionable, but they are also a source of overlapping. The *adaptability* and the *mobility* are additional features for only some kinds of agents (adaptive and mobile agents) (Beydoun et *al.,* 2009; Wooldridge, 2009). In addition, we believe that the intelligence is ambiguous concept which overlaps with other features. Wooldridge (2009) made clear that the reactivity, the pro-activeness and the social ability are suggested capabilities of an intelligent agent. We see also that the adaptability is an advanced capability of the intelligence.

After selecting the main features of MAS, we formulate them according to the ISO/IEC 25010 sub-characteristics' definitions. This formulation allows us to check the suitability of these features according to the ISO/IEC 25010 sub-characteristics. Consequently:

- **The Autonomy:** the degree to which an agent has a control over its state and its behaviour.
- **The Situatedness:** the degree to which an agent is able to perceive and act on its environment.
- **The Reactivity:** the degree to which an agent is able to perceive the occurred changes and to provide timely responses to them in order to achieve its goals.
- **The Pro-activity:** the degree to which an agent is able to take the initiative in order to satisfy its requirements.
- **The Social Ability:** the degree to which an agent is able to interact with other agents to satisfy its purposes.

The suitability of these features according to the ISO/IEC 25010 sub-characteristics is checked in order to identify the limits of such model to specify the quality of MAS. By *suitability* relationship we mean that the definition of the agent's feature is partially or completely covered by the definition of the quality sub-characteristic. Because of the limit size of this paper, we cannot present all the combinations (quality sub-characteristic, agent feature). So, here we present only the essential combinations.

The ISO/IEC 25010 defined the *confidentiality* sub-characteristic by (ISO/IEC, 2011) "*the degree to which the software product provides protection from unauthorized disclosure of data or information, whether accidental or deliberate*". Knowing that the agent states are represented by a set of information and knowledge, we can conclude that the *confidentiality* sub-characteristic cover partially the *autonomy* concept. In fact, protecting of these knowledge and information from unauthorized accesses provides to the agent the control over its state. In addition, the *accountability* sub-characteristic ("*the degree to which the actions of an entity can be traced uniquely to the entity*" (ISO/IEC, 2011)) is strongly close to the ability of the agent to control its behaviour. So, the two aspects of the autonomy feature (the control of agent

state and the control of the agent behaviour) are both covered by the ISO/IEC 25010 sub-characteristics (respectively by the *confidentiality* and the *accountability).*

The social ability designates the ability of the agent to interact with other agents. This interaction represents the ability of the agents to operate cooperatively in order to meet their purposes. As a result, the interoperability ("*the degree to which the software product can be cooperatively operable with one or more other software products*" (ISO/IEC, 2011)) is an adequate concept to represent the social ability in the ISO/IEC 25010. Moreover, the social ability implies the co-existence of the agents in some environment and sharing common resources with possible conflict relationships. The co-existence as "*the degree to which the software product can co-exist with other independent software in a common environment sharing common resources without any detrimental impacts*" (ISO/IEC, 2011) is fully correspondent to the latter aspect of the social ability.

The situatedness refers to the ability of the agent to interact with its environment. Abstracting the environment by a set of objects that composed it, we can consider the interoperability as a strong candidate to cover the ability of the agent to operate with the environment objects. However, more depth analysis shows the drawbacks of this first opinion. Firstly, the interoperability in the ISO/IEC 25010 refers to the ability of the software product to be operable with one or more other *software products*. Thus, the objects which composed the environment of the agent should be, in this case, of software nature. However, the environment of MAS can be either of physical or software nature. In addition, the interaction according to the above definition of the interoperability is summarized on the "*operability with the objects*". It does not provide the possibility of carrying out action on these objects, which is a fundamental aspect in the situatedness feature. For these reasons, we can say that the situatedness is not covered in the ISO/IEC 25010.

The reactivity is the ability of the agent to perceive changes that are occurred in its environment and gives timely responses to them. So, this feature outlines two basic operations: perceiving the environment and giving timely responses. There is no sub-characteristic in the ISO/IEC 25010 corresponding to observe the environment. The timely responses can be ensured by the time behaviour which is defined as "*the degree to which the software product provides appropriate response and processing times and throughput rates when performing its function, under stated conditions*" (ISO/IEC, 2011).

Finally, we cannot find any sub-characteristic of ISO/IEC 25010 that covers the ability of the agent to take the initiative in order to satisfy its requirements (the pro-activeness).

The previous analysis gives the following results: the autonomy and the social ability are adequately covered by the ISO/IEC 25010 sub-characteristics but the situatedness and the pro-activeness are not. In addition, the reactivity is partially covered by this quality model. Thus, the ISO/IEC 25010 cannot express the following specificities of MAS:

- The ability to exhibit goal-oriented behaviours.
- The ability to perceive and act on the environment.
- The ability to perceive changes occurred in the environment.

We formulate these features in a consistent way to avoid the possible confusion and to be compatible with the form of the ISO/IEC 25010 sub-characteristics. Consequently, the following notions are presented as the specific sub-characteristics for MAS:

- **The Proactive-ability:** is the degree to which the agent is able to take the initiative in order to satisfy its goals.
- **The Act-ability:** is the degree to which an agent is able to carry out actions on its environment in order to satisfy its goals.
- **The Perceive-ability:** is the degree to which an agent is able to perceive and detect changes that are occurred in its environment.

Finally, we extend the ISO/IEC 25010 quality model by adding the above sub-characteristics. Hence, the proactive-ability is added to the functional suitability characteristic; the act-ability and the perceive-ability are added to the compatibility characteristic.

Compared to the model of Alonso et *al.,* (2008), this extended version of ISO/IEC 25010 specifies the quality of MAS according to the international standard framework. Moreover, we choose carefully the specific features of MAS in order to avoid confusion and to ensure a wide applicability of our proposed extension. In addition, our proposal is open to possible extensions to support more specific kinds of MAS (like mobile agent).

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5 CONCLUSIONS

The multi-agent systems represent an ideal software paradigm to develop complex systems. As all software products, their quality is an essential requirement. In order to understand and evaluate the software quality, several models are proposed. Some proposed models are the subject of the standardization by the ISO.

This paper addressed the quality of MAS. Its main purpose is studying the ability of applying the international standard quality model ISO/IEC 25010 to MAS. Because of the confusion which may arise from the diversity of the specific quality models, we think that using the ISO/IEC 25010 to MAS is more beneficial than the development of specific quality model for such systems.

The suitability of ISO/IEC 25010 quality model to be applied to MAS is studied according to the weak notion of agency. Thus, we proposed some extensions to support the specificities of such systems. The proposed extensions consisted of adding the proactive-ability, the act-ability and the perceive-ability as sub-characteristics to ISO/IEC 25010 to reflect, respectively, the pro-activeness, the situatedness and the reactivity features. Based on the weak notion of agent, our work is extensible to cover other features of agents.

This work in progress is only the first step in the study of the quality of MAS. As future works, we plan to extend this actual version to support more features of specific kinds of agents (such as the cognitive agent, the adaptive agent and the mobile agent). Furthermore, it seems useful to apply other standards of the SQuaRE series to measure the quality of MAS.

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