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A Framework to COTS Component Selection and Evaluation Processes

***Abstract**. The process of knowledge acquisition of COTS (Commercial Off-The-Shelf) components may provide many difficulties. The existence of a huge amount of diffused information is one of the existing inconveniences related to the selection process. Furthermore, the problem of a choice of a proper methodology supporting COTS component selection and evaluation processes is characterized by a high level of complexity. This paper presents a framework to COTS component selection and evaluation processes. The framework to support COTS component selection and evaluation processes should improve the process of knowledge acquisition of COTS components and methodologies supporting COTS selection and evaluation.*

***Streszczenie.** W artykule podjęto problematykę procesu pozyskiwania wiedzy o składnikach COTS oraz wskazano trudności związane z tym procesem (m.in. dobór właściwej metodologii, rozproszenie wiedzy). Przedstawiono propozycję rozwiązania - framework wspomagający proces doboru i oceny składników COTS, którego głównym założeniem jest usprawnienie procesu pozyskiwania wiedzy na temat składników COTS oraz metodologii wspomagających ich dobór i ocenę. (**Framework wspomagający proces doboru i oceny składników COTS**).*

Keywords: COTS, ontology, COTS methodology, COTS component selection and evaluation, COTS framework.
Słowa kluczowe: składniki COTS, ontologia, metodologie wspomagające dobór i ocenę COTS, framework COTS

Introduction

The COTS products play an important role on the market. They are defined as ready to sell products, available in many copies with minimal changes. Moreover, COTS can be integrated with many different information systems. Additionally they can be a part of bigger and more complex system called COTS-Based System (CBS) [1-3]. The growing popularity of COTS components and the huge number available on the marketplace causes the data and information redundancy for a decision-maker. It is worth to emphasise that the knowledge about them is relatively low. A decision-maker has to review a long list of COTS products to find a set of solutions that fulfil pre-defined requirements. However this does not guarantee a proper choice.

The choice of appropriate software components from any number of available software solutions is one of the most important issues in the selection and development process of an enterprise's Information System. The existence of an enormous amount of diffused information is one of the existing inconveniences related to the selection process [5]. Moreover it could increment the risk of the decision making process. The process of knowledge acquisition about COTS components very often provides many obstacles and is time consuming [4]. It may be supported by available solutions such as components repositories, reports, expert opinions or the results provided by traditional search engines. It is worth to notice that traditional searching mechanisms (e.g. Google) do not include specified COTS functionalities, and they provide an incomplete set of results. The internet is a huge ocean of knowledge, embedded in a many web pages to be checked to find relevant information. On the other hand, information provided by a vendor is subjective. This process is complicated due to the lack of common standard of documentation [6]. The problem cannot be solved by available COTS component repositories. The analysis of the selected solutions denotes that many of them are incomplete, not updated and developed for years. Another issue is an expert opinion and a report, but they are not created frequently, and they are not commonly available

The huge number of components and methodologies causes information redundancy for a decision-maker. Another problem is how to find relevant information in an efficient way. These reasons have an impact of the forming the framework to COTS component selection and evaluation processes. The general aim of this paper is to provide a complex and integrated framework to COTS component selection and evaluation processes. It consists of the three main phases: methodology selection, COTS ERP components selection and COTS components evaluation. The framework requires a construction of two separated ontologies (the ontology for methodologies supporting COTS component selection and evaluation processes and the ontology for COTS ERP components). The proposed framework may improve the process of knowledge acquisition of COTS components and methodologies supporting COTS selection and evaluation processes.

Furthermore, in this paper two separated ontologies are presented. A process of the ontology construction is described in details. The basis for the ontology construction is the analysis of available methodologies supporting COTS component selection and evaluation (1st ontology) and COTS ERP components (2nd ontology). In the section 5-6 a practical usage of the proposed framework is introduced. As a final result, a process of COTS component evaluation is presented.

A comparison of available approaches to COTS components selection

The process of knowledge acquisition of COTS components may provide many difficulties. Furthermore, it is time consuming and it does not provide the expected results. The existence of an immense amount of diffused information is one of the existing inconveniences related to the selection process. In practice, traditional search mechanisms reduce the relevance of search results, providing a set of sub-sites with incomplete information [6]. The possible alternatives to knowledge resource acquisition (such as COTS component repositories, semantic techniques, independent reports, expert knowledge) are still in development phases. It has been observed that COTS component repositories available on the market are excessively general solutions and it is difficult to use them for a specified domain. Owing to the huge number of COTS components on the market, a general repository application could not cope with the basic demands and requirements of decision makers, nor the functional conditions required by a particular domain either. Nowadays a small number of

COTS repositories (e.g. COTSTrader, CLARiFi, CeBASE COTS Lessons-Learned Repository) sup-porting selection and evaluation processes exist in the market, but these solutions may be inadequate through continuous development of the COTS marketplace [9]. It is seemed that they are not developed and updated for years [4, 7, 8]. Another alternative for knowledge acquisition about COTS components is taxonomy (e.g. GOThIC) [6]. However, the information about software components included in a taxonomy system are scattered, only encompassing a short or even lacking a well-defined description of collected components. Moreover, both the precision and trustworthiness of collected information is not well documented [5]. The analysis of the available solutions indicates the lack of existing ontology supporting COTS component selection and evaluation.

This short characteristic of available possibilities of COTS component selection emphasizes a range of this problem. It is worth to notice that this problem is undertaken in many researches for years. The evolution of a COTS software evaluation process is driven by the development of the evaluation tools, new technologies and the enter-prise requirements for its continuous development. The existence of repeatable and organized methodologies for software evaluation improves the whole decision-making process of software selection and decreases the eventual negative consequences. In literature, many approaches for COTS selection are described. Most of them concentrate on a theoretical aspect (COTS methodologies) and provide a set of guidelines of COTS component selection. Apart from this, a practical aspect of COTS component selection occurs in last decade. On base of COTS methodologies, frame-works and information tools offer a wide scope of their practical applications.

A basic approach for COTS component selection is OTSO proposed by Kontio et al. in 1995 [10]. On base of this, the next methodological approaches are created. It is worth noticing that the available methodologies present the evaluation process of COTS components in different ways, but some of them does not propose a novel solution, but only provide an extension of existing ones. The solutions supporting COTS component selection concentrate on many heterodox approaches, e.g. game theory (Teltumbde), optimization techniques (Merad and Lemos), requirement analysis (CARE), heuristics algorithm (RCPEP), quality aspects (COSTUME), requirements engineering (MRETS), fuzzy set theory (Wei and Wang), social-technical aspects (STACE). The latest solutions propose the application of hybrid methods or mixed techniques for COTS evaluation. The schema of COTS methodologies evolution is presented in details in [9].

The different types of specification, heterodox methodological approach and possible spectrum of practical applications conduces information maze for a decision-maker. The problem of a proper methodology selection is characterized by a high level of complexity. Moreover, a decision-maker does not have appropriate knowledge, firstly: how to find the right methodology for a given decision-problem, and secondly: how to find a set of COTS components. The existence of an enormous amount of diffused information is one of the existing inconveniences related to the selection process. In view of the indication the framework to COTS component selection and evaluation is proposed.

A framework to COTS component selection and evaluation processes

An ontology is defined as a formal conceptualization of the world. In information science, an ontology represents knowledge from a formal way, as a hierarchy of concepts for a given domain. It provides a vocabulary to describe types, object properties and relationships between concepts. Ontologies and taxonomies are increasingly used to semantically categorize or annotate information, especially on the web [11].

A framework to support COTS component selection and evaluation processes should improve the process of knowledge acquisition of COTS components and methodologies supporting COTS selection and evaluation. The general aim of proposed approach is to present and provide a systematic approach to COTS component selection. It consists of the two steps: 1st step encompasses knowledge management (in two domains: COTS methodologies and COTS components), and 2nd step involves knowledge application in selection and evaluation processes. The proposed framework consists of three main phases (fig. 1).

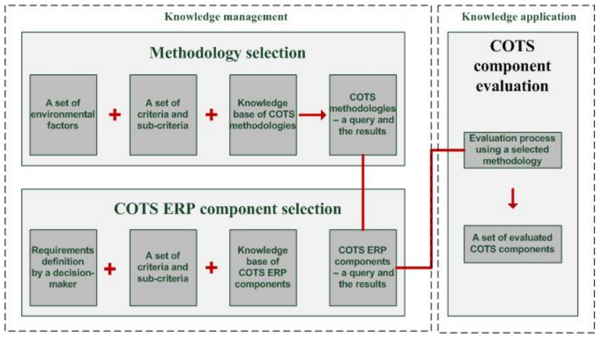

Fig.1. A framework to COTS component selection and evaluation processes

First step consists of the 2 following phases. In the first phase, a selection of a methodology is presented. An exemplary set of preferences is defined by a decision-maker. Then, a practical usage of the ontology for COTS methodologies is introduced. A reasoner (on base of a posed query) provides a set of results that fulfills these requirements. It is possible to change, modify or pose a new query. A level of specification is qualified by a decision-maker. The second phase encompasses a selection process of COTS ERP components. Likewise, an exemplary set of preferences is defined by a decision-maker. An application of ontology provides a set of COTS ERP components, taking into consideration a set of pre-defined requirements. Similarly, a decision-maker may change, modify and define a new set of preferences.

The second step is the final step of COTS components selection and evaluation. It results from the two mentioned phases before. Based on the set of selected methodologies (or methodology) and the set of COTS ERP components (or component) a decision-maker may start the evaluation process. A decision-maker proceeds with reference to the guidelines for a given methodology.

The proposed framework is composed of the following two separated ontologies: the ontology for methods supporting COTS component selection process, and the ontology for COTS components. It is worth to emphasize the role of this proceeding. A construction of two separated ontologies provides a specified knowledge about a given domain of interest. It is not a good idea to face these two ontologies in one application because of the different specification of descriptions. A construction of two separated ontologies enables better understanding of the domain, and provides more precise description of a given domain. Another important issue is that it may be difficult to create only one common taxonomy both for the components and the methodologies. A high level of specification of domain ontology requires separated relationships, classes, sub-classes, types and object properties for each of them. The main advantage of the proposed COTS ontologies is to provide systematic and repeatable knowledge about available COTS ERP components and methodologies supporting COTS component selection process. Proposed framework provides mechanisms for updating information about particular components and methods, and extracting the information about these components according to inquiries defined by a decision-maker. It is premised that the ontologies for supporting COTS component selection enables a reduction in most research problems (e.g. knowledge systematization about COTS methodologies, the choice of a proper methodology for a given decision problem).

Table 1. A specified descriptions of phases of the proposed framework

Name of phase	Description
Methodology selection	It supports a decision-maker in an evaluation process. It includes requirements definition by a decision-maker, and on base of this, a set of criteria and sub-criteria is defined. The final query is posed. The application of author's ontology supports in defining requirements. The reasoning mechanism provides a set of results (methodologies) with regard to the pre-defined requirements.
COTS ERP component selection	It includes requirements definition by a decision-maker. Based on this, a set of criteria and sub-criteria is defined. The final query is posed. The application of author's ontology supporting COTS ERP components selection helps in defining requirements. The reasoning mechanism provides a set of results (COTS ERP components) with regard to the pre-defined requirements.
COTS component evaluation	The application of both ontologies (the ontology supporting COTS component selection and evaluation and the ontology for COTS ERP components) indicates the preferable methodology (or methodologies) and the set of COTS ERP components. A decision-maker selects the methodology. The ontology for methodologies provides a specified description of each of analyzed solution and its usage. The evaluation process of COTS ERP components proceeds thoughtfully and accurately. The final result is a ranking of alternatives. The analysis of obtained results indicates the best-fitted system for decision-maker preferences. The final decision is taken by a decision-maker.

The proposed framework should improve the process of knowledge acquisition of COTS components and methodologies supporting COTS selection and evaluation. The main advantage of the proposed solution is to provide systematic and repeatable knowledge of available COTS ERP components and methodologies supporting COTS component selection process. Furthermore, the framework provides mechanisms for updating information about particular components and methods, and extracting the information about these components and methodologies according to inquiries defined by a decision-maker. It is premised that the ontologies for supporting COTS component selection enables a reduction in most research problems (e.g. knowledge systematization of COTS methodologies, the choice of a proper methodology for a given decision problem).

A procedure of ontology construction

The whole procedure of ontology construction is based on the approach proposed by Noy and McGuiness [12]. The basis for the ontology construction was a thorough analysis of considered solutions and then the experiment of identification of the set of criteria and sub-criteria that were used to create the taxonomy. The defined set of criteria was a basis for a taxonomy construction for methodologies supporting COTS component selection and evaluation. The aim of the taxonomy is to ensure systematization and classification for particular solutions. The taxonomy was a basis for an ontology construction as a next step. The general structure of ontology encompasses the following phases: (1) identification and selection of available solutions, (2) specified characteristics of selected solutions, (3) defining a set of criteria and sub-criteria, (4) taxonomy construction, (5) ontology, (6) process of defining classes. The next phases: (7) reasoning process, (8) consistency verification and (9) a final set of results are begun when the ontology was built.

The ontologies were built using the Protégé application. A standard of the ontology description is OWL (Ontology Web Language). The aim of first ontology is to provide knowledge systematization about available methodologies supporting COTS component selection and evaluation (http://www.semanticweb.org/ontologies/2013/Ontology1292334387792.owl). The ontology provides the information about 38 methods and techniques. The second ontology supports COTS ERP component selection and it includes the specified characteristics of 50 COTS ERP systems (http://www.semanticweb.org/ontologies/2013/Ontology1277282694667.owl). The specified analysis of available solutions allows defining the set of classes and sub-classes for each of proposed ontologies.

Ontology for methodologies supporting COTS component selection and evaluation processes

Ontology for methodologies encompasses a set of 38 different solutions: APCS, CAP, CARE, CBCPS, CDSEM, CEP, CSID, COSTUME, COTS-Agent Based System, CRE, Cil, Colombo and Francalanci, DBCS, Erol and Ferrel, FCS, GOThIC, IusWare, Jung and Choi, Lai, MAS, MRETS, Merad and Lemos, MiHOS, Morera, OTSO, PECA, PORE, RCPEP, SCARLET, SMI, STACE, Scenario-based technique, Sedigh Ali, StoryBoard, Teltumbde, Wang, Wei and Wang, WinWinSpiral Model [9].

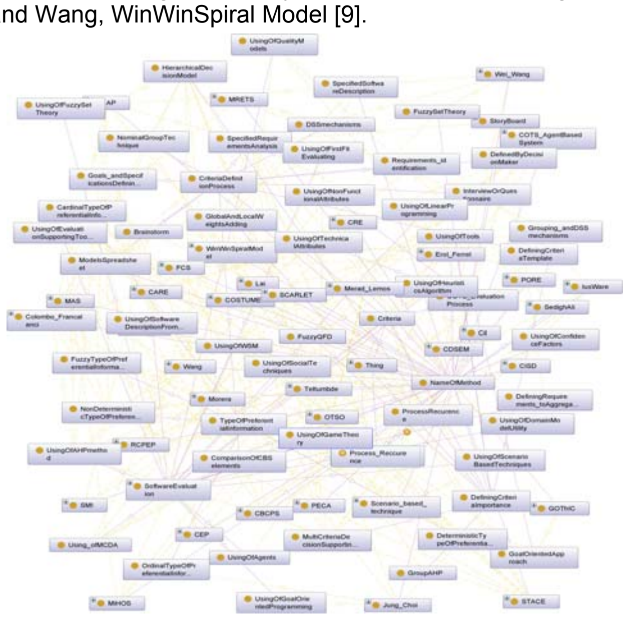

Fig.2. Classes and relations in the ontology for methodologies

A basis of the ontology construction was an analysis of presented above methods. The analysis allows to identify the essential features. It was a crucial element for a taxonomy construction as a next step. It consists of consists of the 5 main classes and 51 sub-classes (fig. 2). The taxonomy construction enables building the ontology.

Ontology for COTS components

Ontology for COTS components contains a set of 50 ERP components. COTS ERP components and their specifications were collected from the extended reports. It is possible to mention that functionalities of COTS ERP components were differentiated, and on base of the reports it was necessary to construct a unified set of criteria for all of analyzed components. As a result of this, taxonomy of COTS ERP components was built. It consists of 19 main classes and 347 sub-classes. Next, the taxonomy was a basis for the ontology construction. Moreover, a formal description of COTS component ontology is provided.

Table 2. A part of formal description of the presented ontologies

Description Logic (a part of COTS ERP ontology)	Class: Logistics Logistics support ≡ System ERP ⊓ ∃ hasCriterion Logistics AssecoSAFO ERP ⊆ ∃ hasCriterion Logistics AssecoSAFO ERP ⊆ ∀hasCriterion (Supply Chain Management ⊔ Human Resources Management ⊔ Transport Management ⊔ Controlling⊔ Services ⊔ ... ⊔ Supplier Relationship Management
Description Logic (a part of ontology for COTS methodologies)	Class: COTS_Methodology ApplicationOf AHPmethod ≡ COTS Methodology ⊓ ∃ hasCriterion UsingOfAHPmethod ApplicationOf HierarchicalDecisionModel ≡ COTS Methodology ⊓ ∃ hasCriterion HierarchicalDecisionModel CaseStudy ≡ COTS_Methodology ⊓ ∃ hasCriterion DeterministicTypeOfPreferentialInformation ⊓ ∃ hasCriterion Goals andSpecificationsDefining ⊓ ∃ hasCriterion HierarchicalDecisionModel

A practical example of the framework to COTS component selection and evaluation processes

A case study is performed on base of presented three phases of the proposed frame-work (fig. 2). It presents a practical example of the application of the created ontologies: ontology for methodologies supporting COTS component selection and evaluation processes and ontology for COTS ERP components. The last phase encompasses COTS components evaluation.

A practical example – methodology selection

A set of decision-maker preferences is selected randomly. It is supposed that a decision-maker is looking for the COTS methodology that fulfills a set of pre-defined requirements. In this case the following requirements were identified by the decision-maker. The preferable methodology should satisfy the following criteria: (1) criteria defined by a decision-maker, or (2) software evaluation: using of AHP method, or (3) criteria definition process: specified requirements analysis, or (4) defining criteria importance: hierarchical decision model (fig. 3).

These requirements are fulfilled by the following methodologies: APCS, CAP, CDSEM, Colombo and Francalanci, COTS ABS, CRE, GOThIC, Jung and Choi, Lai, MAS, Merad and Lemos, Morera, OTSO, PECA, PORE, RCPEP, SBT, SCARLET, SMI, STACE, StoryBoard, Teltumbde, Wang, and Wei and Wang.

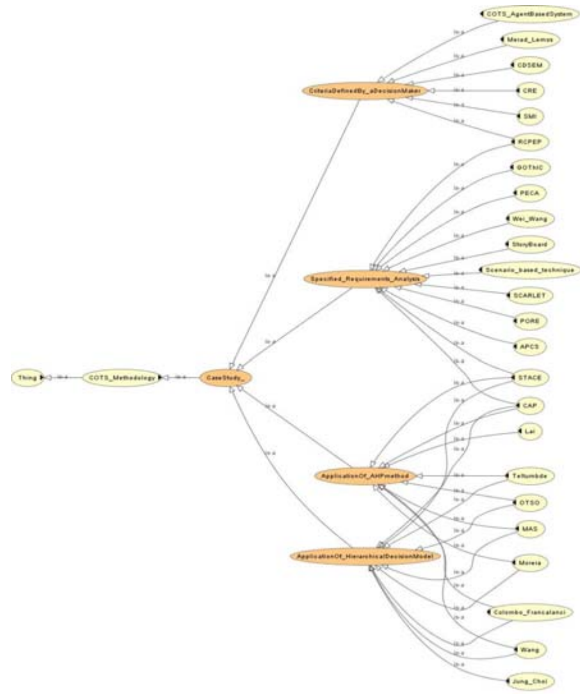

Fig.3. A practical example of COTS methodology selection

A number of methodologies is still huge, and it is seemed that it may not help in a selection process. Due to this situation, the set of criteria is reduced, and the assumptions are changed (fig. 4). It is obliged that a methodology should satisfy all of the criteria. It is the main difference between this case and the case presented before. The new request is composed of the following criteria: (1) software evaluation: using of AHP method, and (2) criteria definition process: specified requirements analysis, and (3) defining criteria importance: hierarchical decision model.

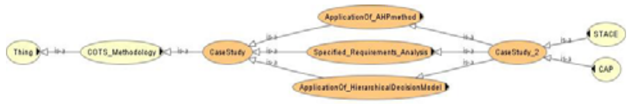

Fig.4. A practical example of COTS methodology selection – a limited set of results

The set of results is reduced to the two methodologies: STACE and CAP. It definitely simplifies a decision process. The ontology for methodologies supporting COTS component selection and evaluation processes provides also a specified description of each of analyzed method.

A practical example – COTS ERP components selection

A set of decision-maker preferences is selected randomly. It is supposed that a decision-maker is looking for the COTS ERP component that fulfills a set of pre-defined requirements. The preferable COTS ERP component should satisfy the following criteria: (1) additional improvements: workflow, and (2) finance and accounts: controlling, and (3) finance and accounts: integration with other banking systems, and (4) logistics and distribution: supplier relationships management (SRM).

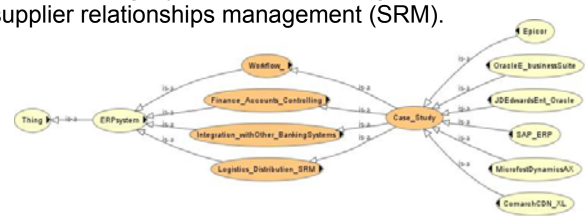

Fig.5. A practical example of COTS ERP components selection

These requirements are fulfilled by the following 6 COTS ERP components: Epicor, Oracle E-business Suite, JD Edwards Enterprise Oracle, SAP ERP, Microsoft Dynamics AX, and Comarch CDN XL (fig. 5).

Next, 5 extra criteria were added: (5) data base: Microsoft SQL Server, or (6) data base: Oracle, and (7) finance and accounts: business intelligence, and (8) size of en-terprise: small enterprise, and (9) size of enterprise: medium enterprise. The set of results is reduced to three COTS ERP components: SAP ERP, Oracle E-business Suite, and Comarch CDN XL (fig. 6).

Fig.6. A practical example of COTS ERP components selection – a limited set of results

A practical example – COTS components evaluation

As a consequence of the performed case study, the obtained set of results is introduced as follows: 2 methodologies: STACE and CAP, and 3 COTS ERP components: SAP ERP, Oracle E-business Suite, and Comarch CDN XL. The process of COTS components evaluation (on base of the methodologies: STACE and CAP) requires the application of analytic hierarchy process method. The criteria definition process is omitted because of the application of COTS ERP components ontology (2^{nd} phase). The ontology provides a set of COTS ERP components, and that is why the process of criteria definition is ignored.

A decision-maker may choose one of the selected methodologies (STACE or CAP). Specified guidelines (how to use a given methodology) are contained in the ontology. As a next step, he has to evaluate COTS ERP components using AHP method. This method enables defining criteria importance by a decision-maker. On base of that the final ranking of preferences is provided, and a decision-maker may make a reasonable choice.

Conclusion

In this paper the framework to COTS component selection and evaluation processes was presented. The general statements of COTS ontology construction were described (section 3). On the basis of specified characteristics of 38 COTS methodologies and 50 COTS ERP components, the ontologies were built using the Protégé application and OWL standard. The practical usage of COTS ontologies was presented. Due to the limited space of publication, only the small portion of the practical application of both COTS ontologies was presented.

The analysis of available approaches indicated the lack of common standard to COTS component selection and evaluation processes. It was seemed that many approaches (presented in section 2 of this paper) were insufficient to ensure a systematic and repeatable way to COTS component selection and evaluation processes. Due to the lack of a complex approach to COTS component selection and evaluation, the framework to COTS component selection and evaluation process was proposed. It consisted of the three main phases: methodology selection, COTS ERP components selection and COTS components evaluation. It required a construction of two separated ontologies (ontology for methodologies supporting COTS component selection and evaluation processes and ontology for COTS ERP components). Based on the requirements defined by a decision-maker the application of each of ontologies provided a set of results that fulfilled these preferences (methodology or a set of methodologies and COTS ERP components). The obtained results from both ontologies permitted the COTS components evaluation in the third phase (the evaluation of the components proceeded according to the guidelines provided by a given methodology). On the output a decision-maker obtained the specified results of evaluated systems.

The main advantage of proposed ontology-based approach is to provide semi-automated solution to COTS component selection. Moreover, a time reduction of the whole COTS selection process takes place. It is seemed that the most important thing is that, a decision-maker does not have a broad knowledge of available solutions, but he can make a reasonable choice. The ontology-based approach has greater possibilities of application than a relational database. The proposed framework might improve the process of knowledge acquisition of COTS components and methodologies supporting COTS selection and evaluation.

The future researches may include an extended framework to other domains of interest, and the ontologies integration as a next step. It may provide more complex and complete knowledge of COTS for a decision-maker.

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