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Onto-Engineering: A Conceptual framework for Integrating Requirement Engineering Process with scientifically tuned Digital Forensics Ontologies

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ABSTRACT

A framework for integrating Requirement Engineering (RE) with scientifically tuned Digital Forensics Ontologies (SDFO) envisages a semantic web-driven approach that is able to provide a shared understanding of unifying RE techniques coupled with digital investigation techniques that are tuned from an ontological perspective. In the context of this paper, RE has been portrayed as a discipline that can not only be able to validate, specify, analyse and provide elicitation of the requirements but also to manage them effectively. Nevertheless, SDFO have been employed as bodies of knowledge that provides a shared understanding of knowledge or discipline within the Digital Forensic (DF) domain that helps to solve some given problems. Mainly, this requires the mapping/integrating of RE processes to DF tuned ontologies. The objective of the work presented in this paper, therefore, is to show how RE can be integrated into SDFO with the aim of identifying the most effective scientific approaches using an Onto-Tuning Matcher (OTM) that has been proposed in this paper. This paper was able to represent a scientifically tuned approach using the Automatic Semantic Mapping of Ontologies (ASMOV) approach. ASMOV provides an approach that is able to align ontologies with other systems such that inconsistencies are eliminated and the accuracy is increased. The contribution of the paper is presented in two folds: Firstly, the author identifies a high-level Onto-Engineered framework for integrating RE and SDFO, thereafter, a more detailed Onto-Engineered framework is discussed. The Onto-Engineered framework that has been discussed in this paper will help to clarify different diversification aspects that exists between RE and SDFO.

KEYWORDS

Onto-Engineered, Framework, integrating, requirement engineering, scientific ontologies, digital forensics.

1 INTRODUCTION

There is need for proper software development processes which are able to address Requirement Engineering (RE) when developing high quality and high-end software. This is because employing RE during software development processes facilitates better development of a system that is able to perform tasks effectively. Notwithstanding that, RE being a systematic process, employing bad RE approaches might lead to failure of software projects. This is because studies have shown that the cost of RE error becomes 100 times higher as compared to the cost of the error during the software development phase, which is an indication that a project's quality is improved with an improvement of the RE [1]. Since software products are developed using the Software Development Life Cycle (SDLC), RE is usually employed as a crucial stage within the SDLC. Being the first stage in the life cycle, RE becomes very important because the requirements to be employed need to undergo a validation, analysis, specification and identification. All these processes are done in order to satisfy the stakeholder's needs and expectations [2].

Ontologies on the other hand, have in many ways been visualised as conceptualisations that can encode constituents of knowledge into a single domain in order to deduce simpler inferences. This is backed up by Grüber [14], who defines ontology as an exhaustive specification of a conceptualisation. Furthermore, they are capable of analysing the structure of the body of knowledge which generates a common definition of knowledge. On the same note, conceptualisation has been represented as an abstract or an item within a discipline that is represented in the semantic web [3]. Different perceptions on how the integration of Scientific Ontologies (SO) has been incorporated in RE have pointed to the following aspects: Being able to solve some specified problems, management of knowledge in RE, improvement of the RE specifications as well as being able to perform analysis processes in RE [3].

Digital Forensics (DF) provides a scientific technique for recovering artefacts from digital devices that can aid in supporting or refuting a hypothesis in a court of law during criminal or civil proceedings. Ontologies in DF are approaches that conceptualises the digital forensic knowledge based on the perceptions that can be used to help prove or refute a fact (occurrence of a digital crime). DF has been represented as an area of focus in this paper because, the DF process are '*ontologized*' and then mapped with RE processes. The integration of these processes with RE ensures that the RE processes can be used in '*ontologized*' DF techniques. This in the long run makes the SDFO to be aligned or scientifically tuned in such a way that they are able to accommodate RE processes easily.

The extent to which the existing research covers SDFO integration in RE cannot be substantiated without an exploration as to whether there can exist a unifying ontologically engineered framework that can enable the integration of SDFO to act as a benefit to RE and vice-versa. Therefore, the research question employed in this paper can be formulated as follows: Can there exist a unifying Onto-Engineered framework that can contribute to the integration of RE and SDFO? The contribution of this paper is thus presented in three approaches. Firstly, the authors explore the current state of art of RE and SDFO by looking at any previous work done, thereafter, a high-level view of the proposed Onto-Engineered framework will be presented, followed by a detailed Onto-Engineered framework.

The remainder of the paper is structured as follows: Section 2 provides background work on Requirement Engineering (RE), Scientific Ontologies (SO) and Digital Forensics (DF). Thereafter, Section 3 concentrates on discussing the current state of RE and SO as part of related work. After that, Section 4 presents the proposed Onto-Engineered framework for integrating RE and SDFO while Section 5 presents a critical evaluation of the proposed concept. Finally, Section 6 concludes this paper and gives indications of future work.

2 BACKGROUND

This section provides background study on the following aspects: Requirement Engineering (RE), Scientific Ontologies (SO) and Digital Forensics (DF). RE has been discussed to show how different software development process activities are handled during RE process. SO is discussed to show how conceptualisation of different pieces of knowledge is represented and how they might be useful when integration is done with RE. Finally, DF is also discussed to show how scientifically proven methods can be integrated to the RE processes when sequenced under SO.

2.1 Requirement Engineering

Requirement Engineering (SE) is a discipline or a branch in software engineering that is capable of handling activities and relationships that deals with different behavioural aspects of software. Hassan et al., [2] has portrayed it to contain the following activities: Requirement Elicitation (RE-E), Requirement Analysis (RA), Requirement Specification (RS), Requirement Verification and Validation (RVV) and Requirement Management (RM). Basically, these processes are bound to vary at different levels depending on the kind of people that will be involved, organisational requirements and the application domain that is being employed. RE-E is a process that is used to determine and discover the needs of the clients or customers to find application domain [4], RA declares exactly what the software project is aimed to achieve [5], RS is used to document and presents a blueprint to the stakeholders for the process of software development [6], RVV acts as a proof that the software product may meet the needs of the stakeholders or customers [2] and finally RM is responsible for ensuring the existing requirements' modification are done in a controlled manner [7]. Figure 1 shows the activities involved in RE. Scientific ontologies are however explained in the sub-section to follow.

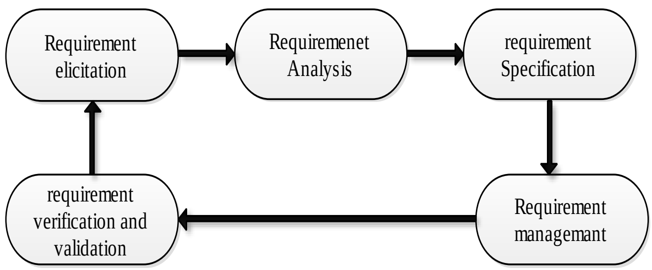

Figure 1. Requirement engineering process

2.2 Scientific Ontologies

The origin of the word ontology can be traced to the Greek word "*ontos*" with a meaning of *being* and the word "logos" that means *word.* Therefore, it has been coined to signify the science of being [14]. Scientific Ontologies (SO) are used to formally represent the structure of a shared understanding of a given domain. Staab et al. [17] adds that ontologies are meant to capture domain information in a generalised way as well as provide a commonly agreed-upon comprehension of the domain, which may be re-used and shared across different applications and groups of people.

An example of ontology may be an organisation that has a number of employees and the relationships that exist between them [8]. Consequently, according to Rajakaruna et al.,[9] SO are employed as mechanisms for modelling Complex Information Systems (CIS) which is becoming a very basic technology that is used to model the semantic web. SO are represented as explicit forms of shared conceptualisations in a given domain that are able to create different forms of relationships and model pieces of concepts that ends up representing the reasoning about a given body of knowledge. According to research by Ma et al., [10] ontologies are able to be used for different projects when designing products, this can only be achieved based on how information of a given product might be disseminated in different domains. Based on this premise, SO is used as a way of representing the domain conceptualisations that is needed by the product if the data semantics have to be captured.

A lot of research work has been done to help in ontology integration. Nevertheless, for any ontology developed to be useful, it must represent a shared, agreed-upon conceptualisation [19], in other words it should be accepted by a group of people or a community. For this reason, ontologies are and should be developed based on a shared, agreed-upon conceptualisation by a group of people or a community.

On this note, Gaevic et al. [20], adds that ontology development is normally a set of established principles, processes, practices, methods and activities used to design, construct, evaluate and deploy ontologies. To build any high quality ontology, Leung et al., [21] state that ontology developers need to select and follow an appropriate development methodology consisting of a sequence of steps, activities and guiding principles that are put together in an organised and methodical way. Gaevic et al. [20] remark that a single, best-known ontology development methodology does not however exist yet, because there is still no consensus about a single 'correct' way to model a domain. Furthermore, while the ontology development process is inevitably an iterative process, the available literature shows that constructing ontologies by reusing available ontologies is cheaper than constructing from scratch.

According to Brusa et al. [22], however, the ontology development process can be categorised into two main steps: a specification step and a conceptualisation step. The primary aim of the specification step is to get informal understanding about the domain, whereas, the aim of the conceptualisation step is to organise as well as structure the domain information with the help of external representations.

Several ontology development methodologies have been proposed in literature by different researchers and research organisations. Most of these methodologies concentrate on building ontologies from scratch. A few others exist, although that includes methods for merging, re-engineering, maintaining and evolving ontologies [20]. Other ontology development methodologies also exist that exploit the idea of reusing existing ontological knowledge in building new ontologies.

Regardless of their high-level specifications, ontologies also permit flexibility. In addition to this, different groups of people or communities build ontologies for different reasons. However, Noy and McGuinness [18] made the following summary of some of the reasons why people build ontologies:

- To share a common understanding of the structure of information among people or software agents.
- To enable reuse of domain knowledge.
- To make domain assumptions explicit.
- To separate domain knowledge from the operational knowledge and finally.
- To analyse domain knowledge.

Concepts of digital forensics as a domain are briefly explained in the next section.

2.2 Digital Forensics

Digital Forensics (DF) as explain by Karie and venter [23] is an evolving field that is gaining popularity among many computer professionals, Law Enforcement Agencies (LEA), forensic practitioners, and other stakeholders who must always cooperate during a digital investigation process. This field, according to Desai et al., [24], has become very important due to the increase in digital crimes. In the context of this paper, the discussion has mainly been focused on the techniques through which domain knowledge from ontologies can be integrated into the RE process.

In a growing field like DF, developing practical methodologies and specifications for different areas of application is thus essential and as important as the research itself [25]. It is on these grounds that this paper proposes a framework for integrating Requirement Engineering (RE) process with scientifically tuned Digital Forensic Ontologies (SDFO).

DF consists of a number of processes that can successfully be tuned in scientific ontologies so that they can be incorporated in RE processes. Example of processes models include: Integrated Digital Forensic Process Model (IDPM) by Kohn, Eloff MM and Eloff JP [31], and a Cloud Forensic Readiness as a Service (CFRaaS) by Kebande and Venter [32].

In a more generalized way the digital forensic process contains different phases as highlighted in the ISO/IEC 27043 international standard. The ISO/IEC 27043 international standard is however handled later in this paper. The current state of the art on requirement engineering and scientific ontology is presented in the next section, followed by an explanation of the proposed framework.

3 CURRENT STATE OF THE ART AND RELATED WORK ON RE AND SO

This section gives an explanation on the current state of the art on RE and scientific ontologies. The section concentrates on presenting an exploratory research based on the existing literature that is somewhat existing as related work and captures the current state of the art on RE and SO as well.

To begin with, research work that used a Semantic Literature Review (SLR) technique has identified different RE techniques that are used in identification, interpretation, synthesising and evaluation of different studies that are aimed at giving answers to different ways ontologies and RE interact. The purpose of using SLR is to present a coherent understanding on how scientific ontologies are able to support RE [3]. Studies have also been done on scientific ontologies and some of the most prominent ones are highlighted briefly in the next paragraphs.

Smith et al. [23] define ontology as an exhaustive formal specification of how to represent entities that exist in a given domain and the different relationships that exist among the entities. For this reason, ontologies in any given domain can speed up discoveries by allowing researchers to quickly find and compare the relationships that exist between data from multiple sources. With the increased use of ontologies in different domains, it has become natural clear that ontology integration is inevitable.

SO integration is thus a process aimed at creating or building a SO in a given subject by taking another SO in a totally different subject [11]. The first step to integrate ontologies is to merge different ontologies to obtain a single ontology which then includes all the knowledge that the merged ontologies have.

A study by Pinto and Martins [12, 13], shows that one can identify the knowledge that is supposed to be represented in each of the given module in the ontology.

In another study by Karie and Venter [25], the authors presented the case for establishing ontology for DF disciplines to enable better categorisation of the disciplines, as well as assist in the development of methodologies and specifications that can offer direction in different areas of digital forensics. The study, however, did not address the problem of integrating RE and SO like the current paper does.

More studies by Karie and Kebande [26] presented the concept of building ontologies for digital forensic terminologies and proposed an ontological approach to resolve the meaning of different digital forensic terminologies. The main problem addressed was that, there exists no approaches in DF that have the ability to help investigators in reasoning with regard to the perceived meaning of different digital forensic terminologies encountered during a digital forensics investigation process. This study however, did not point out the integration of RE and SO which is what the current papers focuses on.

This paper, therefore, focuses on developing a framework for integrating RE with SO. Other research on the integration by Kebande and Karie [33] focused on multimodal biometrics which gives a desirable approach worth exploring towards the integration with RE. In the next section, the proposed framework for integrating requirement engineering with scientific ontologies is explained.

4 ONTO-ENGINEERED FRAMEWORK FOR INTEGRATING REQUIREMENT ENGINEERING WITH SDFO

This section presents a framework and the concepts for integrating Requirement Engineering (RE) and Scientific Digital Forensics Ontologies (SDFO) as a contribution. The proposed framework has been represented in two approaches. Firstly, Figure 2 shows a high-level overview of the Onto-engineered framework and then a detailed framework is discussed using Figure 3. Thereafter a discussion on the components of the Onto-engineered framework is given.

4.1 High-level overview of Onto-Engineered Framework

The high-level view of the framework is divided into three distinct parts namely: Requirement Engineering (RE) shown by the rectangle labelled 1, Onto-Tuning Matcher (OTM) shown by the rectangle labelled 2. Lastly is the Digital Forensics Process that is labelled 3.

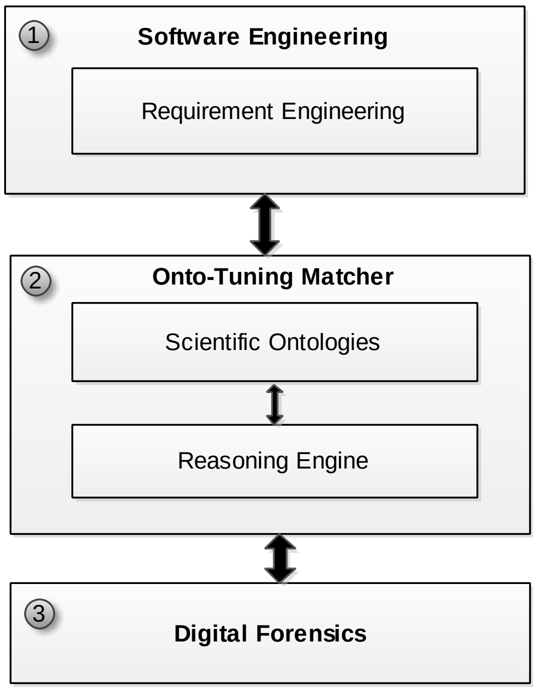

Figure 2. A high-level overview of the onto-engineered framework

RE represents a software engineering phase that is used to create relationships and behavioural aspects of the software as described in (Section 2.1), OTM represents the conceptualisations that represent shared pieces of knowledge that matches and breaks them to simple inferences. Reasoning engine acts as system that can infer logical attributes from a set of facts. More details of the high-level are illustrated in the detailed framework that is discussed in the next section. Digital Forensics (DF) process represents the scientifically proven digital investigation processes that can be used to bring out the conceptualisations through the application of ontologies and integrating them to the RE process.

4.2 Detailed Onto-Engineered Framework

The detailed Onto-Engineered framework which is an extension of the high-level framework discussed in Section 4.1 (see Fig 2) and consists of three distinct parts labelled 1-3. Requirement engineering labelled 1, Onto-Tuning Matcher (OTM) labelled 2 and DF that is labelled 3 respectively.

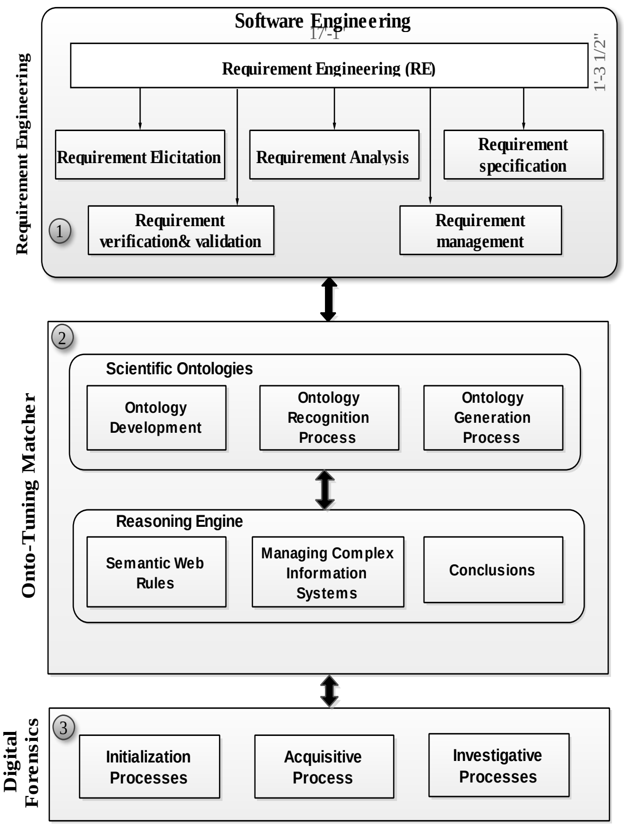

Figure 3. Detailed Onto-engineering framework

OTM is further divided into scientific ontologies and a reasoning engine. Each of the components of the detailed model has been explained below.

4.2.1 Requirement Engineering

Requirement Engineering (RE) consists of the following components: Requirement Elicitation (RE-E), Requirement Analysis (RA), Requirement Specification (RS), Requirement Validation and Verification (RVV) and Requirement Management (RM). All these components were previously discussed earlier in Section 2.1 are fed into the scientific conceptual domain that represents the scientific ontology in an integration process. This has been shown in the uppermost rectangle that is labelled 1 in the requirement engineering process of Figure 3.

RE-E with respect to the Onto-Engineering framework has been presented as a critical step which requires an understanding of the collection of system requirement processes. Ontologies on the other hand present a very concise and important process in this step. While ontologies focus on representing knowledge across different domains, it is still vital to map them to elicitation processes such that the set of concepts that are contained in the elicitation process can be able to present specialised knowledge in the perspective of ontologies. This is only possible if RE-E are mapped or aligned to the scientific processes that are represented by ontologies. Scientific ontologies are bound to create a relationship between the elicitation process and this should be done through ontology alignment. Ontology alignment has been highlighted as a way of matching approximation of a common ideal ontology through mapping. [27], [28].

The DF processes in Requirement Analysis (RA) helps to track existing inconsistencies through digital investigation. Also, it checks the incompleteness that allows the quality of what is presented in RE to be questioned. RA can be used to create a relationship when DF processes are employed. A scientific ontology in this context presents the concepts that can be used to deduce or interpret how DF processes are conducted in RA.

Requirement Specification (RS) employs ontological abstractions that allow ontologies to model some attributes based on some fixed syntax elements. This can be achieved by employing ontologies to set conditions that the system components can satisfy. Through this approach, ontologies can be used to conceptualise the conditions set by RS.

Based on the elicited processes, requirement verification analyses those processes using refined ontologies by passing them through a verification engine to allow examination. This examination process uses ontologies that are also aligned to the examination process in digital forensics. It involves scrutinising the processes so as to excavate some knowledge through characterisation. Characterisation can be achieved by passing the examined processes through a validation engine. Finally, through control, all the processes can easily be handled by the requirement management module.

4.2.2 Onto-Tuning Matcher

Onto-Tuning Matcher (OTM) phase labelled 2 provides a tuning or mapping of DF ontologies into RE. This is done with respect to their features and weights. The main reason for tuning is to either get the semantic correspondence or similarity that exist between the RE processes and the DF processes. The authors have described the concepts that have helped to integrate RE and DF. On the same note, the OTM is able to identify the processes that should be tuned based on the features of the ontology and display the processes directly.

Using the OTM it is possible to represent a tuned approach using the Automatic Semantic Mapping of Ontologies (ASMOV). ASMOV provides an approach that is able to align ontologies with other systems such that inconsistencies are eliminated and the accuracy is increased.

The ASMOV is able to compute the similarity between two processes while integrating them in order to show how closely they match and if they have some common features. This can be achieved through analysing entities and modelling them into ontology. This similarity can either be a semantic, lexical or individual features similarity. For example, if we take a set of features to be ***x*** and some entities that represents the RE and DF processes to be e_1 and e_2 respectively, then the similarity [29] of this processes can be calculated as follows:

$$S(e_1,e_2)=\frac{\sum_X w_i x Sm_1(e_1,e_2)}{\sum_X w_i} \tag{1}$$

Where w_i is the weight that is assigned to each process (feature). Alternatively, the similarity of the RE and DF can be calculated using the Similarity Measure (SM) based on the Euclidean Distance, which is used to check how similar two events can exhibit similarities as shown by Kebande and Venter [30] as follows:

$$SM_1=\sqrt{\sum_{i=1}^{p}(V_{ij}-V_{jk})^2} \tag{2}$$

It is evident that calculating the similarity of the RE and DF processes can have different effects on the probability on how the processes are mapped between the scientific ontologies.

Based on Table 1 the RE and DF processes have been successfully mapped based on the similarity of the processes.

Table 1: Tuned/Mapped RE-DF processes

DF/RE	RE-E	RE-A	RS	RM	RVV
Planning					
Collection					
Seizure					
Acquisition					
Analysis					
Reporting					
Closure					

Each of the mapped process has been represented with a shaded region in Table 1. The processes have been mapped as follows: <Requirement-Elicitation> is mapped to [Planning], [collection] and [seizure] while <Requirement–Analysis> has been mapped to [Analysis] process. Next <Requirement-Specification> has not been mapped to any process while <Requirement-Management> has been mapped to all the digital forensic processes. Lastly, <Requirement Validation and Verification (RVV> has been mapped with [Analysis] process.

4.2.2.1 Scientific Ontologies

The scientific ontology process has been shown using the rectangle that is labelled 2. It consists of the following components: Ontology development, ontology recognition process and ontology generation process. Ontology development process represents the building of requirement engineering sets of knowledge, concepts and terminologies within the scientific ontology domain. Next is the recognition process which allows the built ontology to be able to categorise and create a relationship between the concepts that have been created. Lastly, the ontology generation process allows the created relationships to be defined using some modelled scientific scopes.

4.2.2.2 Reasoning Engine

Reasoning engine has been represented with the rectangle that is labelled 3. The reasoning engine which can also be called a rule engine or a semantic web reasoning engine acts as an inference point that is used to put together the different Onto-Engineered pieces of knowledge into some taxonomical approach to bring out the meaning. This is done using the semantic repository shown in Figure 3. It consists of the following: semantic web rules, modelling of Complex Information System (CIS) rules and conclusions. Semantic web rules is used to present inferred logical Onto-Engineered aspects that have been integrated, thereafter the same rules can be used to model CIS. Lastly, the engine is able to generate conclusions based on Onto-engineered knowledge based approach shown in rectangle labelled 2.

4.2.3 Digital Forensics

Based on the guidelines that have been mentioned in the ISO/IEC 27043 international standard, the digital forensic process that have been represented in the part labelled 3 of Figure 3 forms part of the reactive process of digital investigation processes. ISO/IEC 27043 is a standard that presents the idealised models for information technology-security techniques-incident investigation principles and processes.

The reactive consists of the three processes: Initialisation, acquisitive and investigative process. The reactive part forms part of the digital forensic processes that have been shown in Table 1 of this paper. The initialisation process is a class that is used to commence the digital investigation process through handling of incident detection, first response, planning and preparation processes.

The acquisitive process class is concerned with approaches that acquire digital evidence. Mainly, this will be concerned with identification, collection, acquisition, transportation and storage processes.

Lastly, the investigative process is a class that deals with how incident investigation techniques are conducted. It deals with analysis process, interpretation, examination, reporting, presentation and investigation closure.

It is worth noting that the aforementioned processes have been mapped to RE processes using an OTM which has provided a technique of integrating RE with SDFO. More on the possible applicability of this research study has been discussed in the next section.

5 CRITICAL EVALUATIONS

There exist few research work that investigates how ontologies can be adopted in software engineering domain let alone in RE with the application of Digital Forensics (DF) [15, 16]. Most of this research work was not able to present a more comprehensive framework that could unify the Onto-engineering integration (RE-SDFO) with high degree of certainty. Discounting that, most of the literature was somehow limited to illustrative scenarios and reviews that tend to highlight how scientific ontologies can be adopted in requirement engineering.

Based on the study and the presentation that has been illustrated in this paper, it is evident that RE is a crucial activity in a software engineering approach and based on the digital investigation techniques, it can be more significant to conceptualise some pieces of knowledge when the RE processes are integrated with tuned DF ontologies. Nevertheless, implementing these processes through ontologies shows that it is easy to excavate some perceived knowledge that can be mapped to RE processes. If there exist some RE processes that are not understood well, then there can exist some ambiguity and inconsistencies during this process. This is the reason why we have suggested the use of ASMOV to test the similarity between the processes so as to avoid inconsistencies and incompleteness when mapping this processes.

Ontologies too can present the conceptualised and simplified visualisation that can help provide fine-tuned process that can be easy to identify while performing mapping. The Onto-engineered framework has actually provided a mechanism for solving this inconsistencies and simplifying the processes.

There exist a number of approaches that have been able to incorporate ontologies to RE process which has been mentioned in related work and background of this paper, however, the proposed approaches have been able to tune digital forensics ontologies to RE. To the best of the authors knowledge, none of those approaches hardly tuned DF process to RE as at the time of writing this paper. Our concepts adds an enormous value to the integration of tuned DF ontologies to RE and it is obvious that this is a research worth exploring.

In this paper, the authors have proposed an effective Onto-engineered framework that is able to integrate RE process to SDFO. Furthermore, this provides a more precise method of understanding how the ontological concepts can be used to identify any availability sematic web overlaps through conceptualisation and inferences of pieces of knowledge. The framework summarises different integration approaches in a conclusive manner and it is the authors' opinion that it can support interoperability in the web.

In the next section, a conclusion and future work is presented.

6 CONCLUSIONS AND FUTURE WORK

The research question that was highlighted in section 1 of this paper addressed the following: "Can there exist a unifying framework that can contribute to the integration of RE and SDFO? "

The authors have answered this research question by proposing an Onto-engineered framework that is able to integrate Requirement Engineering with Scientifically tuned Digital Forensics Ontologies (SDFO). The authors also presented the current state of the art of ontologies and Requirement Engineering (RE) process. The work in this paper has been able to show how ontologically tuned digital forensic processes can be mapped to RE processes.

For future work, the authors aim to build a generic self-tunic ontological tool that is able to directly match all processes at once and be able to distinguish, characterise the knowledge behind each process by taking into account the assigned weight and the features. This will involve simulating the processes using a working RE-SDFO prototype.

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