International Journal of Grid and Distributed Computing
Vol. 14, No. 1, (2021), pp. 332-345

A Generic Framework: Root Cause Mining Integrated with Requirement Engineering Process for IOT Applications

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Abstract

The research work presented here deals with the requirement engineering process for public domain based IoT application. The innovation in this context is root cause mining. The root cause analysis is a popular technique to find out the root causes of a particular event by utilizing the manual or tool based tracing techniques. In this paper, we have extrapolated the existing concept by replacing the techniques to identify the root causes. We are introducing a novel concept called root cause mining, we have incorporated knowledge text mining in order to identify the root causes. Collectively we are introducing a new concept called root cause mining(RCM). The root cause mining has replaced the requirement elicitation process in some specific exceptional cases. This approach is well suited where we want to develop applications to overcome from the system failure or whenever we need to develop an IOT application to take preventive measures to avoid the fault to occur. In this work, we are proposing a framework for the requirement engineering(RE) process for public domain based Internet of Things (IOT) application. The capacity of the root cause mining as a sub process is not only limited to the IOT based application; it can be also fitted for any requirement engineering process wherever requirements are needed to gather from multiple sources from various viewpoints in search of root causes to develop the application to handle the fault occurrence.

INDEX TERMS *Root Cause Mining, Data Mining, Electrical accidents, Electrical fires, Internet of Things,*
Requirement Engineering, requirement elicitation, Text mining, Opinion mining, Web mining.

I. INTRODUCTION

The fabric of the world is becoming intelligent and responsive with the advent of IOT. The IOT has blurred the differences between the digital universe and the physical universe. The traditional requirement engineering is obsolete with respect to IOT. Finding out the requirement to

ISSN: 2005-4262 IJGDC

implement the IOT application for the smart cities required energy management to handle the assorted IT device and the mountains of post processed data [1].

Viewpoint oriented requirement methodology [2] was introduced almost two decades back but researchers used this method for different perspectives [3]. Opinion mining and natural text processing is very young and untouched to explore and fit into the various problem solving. This is another effort to bridge the gap between software engineering and data mining. Data mining is matured enough as it's been in practice since a long time but after big data analytics and data science revolution data mining practices accelerated to get a plethora of new acumens [4].

The current work emphasizes on novel root cause mining to elicit the IOT requirements. Data mining discovers required information hidden in large troves of data. Mined data is analyzed to determine patterns and irregularities in sets of data. Applying data mining in requirement elicitation is a unique analysis method [5]. Natural language processing could be used as automated form to replace the user requirement [6] especially when the requirements need to consider from the multiple public viewpoints in order to build a software application or any IOT based solution, whichis commonly designed for public use such as implementation of IOT based solution to avoid the electrical accidents.

This paper is organized as follows: Section II includes Motivation. The circumstances that led to discovery of the novel requirement engineering process is explained here. Section III contains relevant research in the field of requirement engineering and specifications in IOT applications. Section IV includes the proposed RCM design structure. Section V raises relevant research questions. The last section comprehends the concluding remarks and future work aiming at the extension of RCM.

II. MOTIVATION

The popular quotation says “Necessity is the Mother of Invention- Plato”. Most of the research directions are derivedfrom the necessity. When we started our research project entitled as "Unifying Requirement Engineering, Machine Learning and Opinion Mining to Implement IOT Solutions: An Effort to Reduce Electrical Fire and Casualties in OMAN" The proposed research is an effort to reduce the electric accidents through the IOT device. Electric fire accidents in Oman increasing very frequently since many years which is causing the serious injuries and unnatural death of innocent Omani civilians, from the electrical engineering perspective overloading of electrical load into the houses is the main cause of electrical fires but it’s not only the factor it could happen due to low quality of the products, continuous use of gadgets could produce the overheating which is unbearable for the electric wires, modifying the fuse wires which is baring the more load which is not recommended and longtime use of electrical wire which is crossing the recommended time period. The electric accidents may be from one of the mentioned causes but to find more appropriate and frequent cause need to conduct the data mining research. The proposed research will find out the most appropriate reason for electrical

ISSN: 2005-4262 IJGDC

accidents from the primary and secondary data set. Opinion mining/natural text processing will be performed based on association rule and frequent growth pattern on the primary data which will be collected from the social media posts such as news articles, social comments, tweets and reviews, data will be fetched using the top notch latest technology called Big Data Analytics/Data Mining tools based on the keyword; electrical accidents in Oman. Data analytics will be also performed in the similar fashion on the secondary data, which will be collected from the National Center for Statistical Information (NCSI). After a comparable study based on the above both analysis requirement elicitation process for the public IOT application will be documented. Interviewing, observation and usually is the proven techniques to understand the client requirement but to finding out the actual need and requirement for the mass use of IOT application required to take viewpoints and opinion from the mass public is quite difficult to perform, instead latest trend of natural text processing on the social media post can be utilized to find out the requirements by applying analytics on different vertical's. In this research, public mass opinion mining will be performed based on association rules and frequent growth patterns to find out the reason for electrical accidents, results will add the value to understand the necessity and the requirement of IOT application to reduce such electrical accidents.

The purpose of performing the above-mentioned analysis is to find out the most frequent and appropriate reason for accidents to recommend the well-suited effective IOT based solution. The proposed research will be carried intend to reduce such incidences in the future and on other hand proposed work will also propose an innovative paradigm to conduct the qualitative research by fusing the Opinion mining, machine learning and Requirement Engineering. Machine Learning models will be constructed on the secondary/primary dataset to predict the future incidences in the upcoming years. This will help us to understand the seriousness to look after the solution to reduce the electrical accidents in order to save the thousands of innocent Omani civilian's lives.

We discovered that the existing requirement engineering for IOT is not capable to solve our problem. The basic pitfalls of the existing RE for IoTis tightlyknit with the requirement elicitation techniques that use the traditional techniques such as interviews, direct observations, document analysis etc. We were looking for a RE framework where root cause analysis can be proven as a list of requirements to prevent the event to occur. To extend our thought we have moved forward to propose a modern requirement engineering process for IoT blending with root cause analysis. During the process of discovery, we realized the traditional method to perform root cause analysis will not be suitable because to find the root causes of a particular event we need to acquire the data from the various sources. In our research project we have decided to first collect the data from Twitter, news portals and other websites where our information is available related to the past electrical fire accidents. Basically, we have many concepts that are text mining and root cause analysis collectively it can be called as root cause mining. Finally, we came across a novel requirement engineering process for IoT with collaboration of root cause mining as a replacement of the requirement elicitation process in some specific cases wherever we need

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to find out the root causes by knowing the facts from different sources which is not available in a single source.

III. RELATED WORKS

Requirements engineering is a first and an important phase in SDLC (Software Development Life Cycle). The Business Analyst or Requirements Engineer is the key person to execute the requirement engineering process. The process uses different tools and techniques. The techniques are classified into four main categories [7]. They are, classical/traditional techniques, cognitive techniques, modern and group elicitation techniques and contextual techniques. The IOT represents a broad vision in which things such as everyday objects, places and environment will be interconnected with one another through the internet [8]. A distributed network environment [9] supports the IOT applications. The distributed environment imposes novel challenges for the requirement engineering process. The regular requirement engineering process of SDLC may not be applicable as it is. In this regard a brief literature review has been carried to identify the related works.

The requirements engineering for IOT systems has three sub processes [10].

1. Project Scope Definition (PSD)
2. IOT System Definition (ISD)
3. IOT System Requirements Definition (ISRD)

The PSD defines the problem and stockholders. The ISD defines the scenarios. The ISRD defines IOT components and verifies the specification.

The IOTReq is a method for extracting and describing the requirements for an IOT system [11]. The IOTReqsuggests to model the domain by service oriented paradigm approach in UML. Next the purpose of IOT system to be built are extracted and described using UML also, i.e. Extending domain model. Additionally,IOTReq also provides specification of non-functional requirements.

A framework based design and analysis process to model IOT application [12]. The framework consists of SysML4IOT and SysML2NUSMV. SysML is a profile developed on the IOT. SysML4IOT converts the model to text. The QoS properties mentioned by translator are executed by NUSMV,NuSMV is a robust model verifier. The System model is inserted in the form of Finite State Machine (FSM). FSM properties are verified as specified in computational tree logic (CTL) or Linear Temporal Logic (LTL).

The quality requirement framework of ISO/IEC 25030 is applied on IOT systems [13]. The Systems and Software Quality Requirements and Evaluation (SQuaRE) has five main divisions. Out of five divisions, ISO/IEC 2503n - Quality Requirements Division is relevant in this context. This division helps specify quality requirements. These quality requirements can be used in describing system/software needs.

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A full automatic framework for modelling and analysis of IOT [14]. Formalism is used to collect the details of the main structure and behavior of IOT entities. The formalism consists of rich and flexible semantics. This is used to collect IOT functional requirements. To check functional correctness, the IOT model is mapped into input language of PRISM.

IOT – Requirements Modelling Language (RML) is used to specify requirements for IOT systems [15]. The RML formalizes functional parameters for the IOT system. The RML also allows representation of QoS parameters as IOT in a multi layered architecture. The RML considers influences and conflicts between requirements. At the end RML generates conflict free candidate solutions.

The TrUSTAPIS, a json based requirement elicitation method to assist developers to elicit IOT requirements [16]. K – Model methodology is used in the requirement elicitation phase. As per this model the requirements are related to seven domains. Each requirement is drafted with respect to seven domains and their characteristics. In this model traceability is an important feature.

IV. RCM design structure

In this research a novel approach to perform the requirement engineering process for public domain based IoT applications will be introduced, the requirement engineering process will be conducted in five different phases as follows:

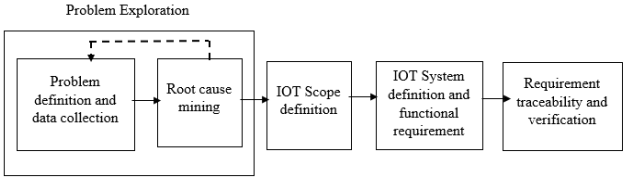

FIGURE 1. RCM based IOT requirement engineering

1. Problem Definition and Data Collection
2. Root Cause Mining
3. IoT scope definition
4. IoT System definition & functional requirement
5. Requirement traceability & Verification

The first two phases are grouped under the problem exploration. The first sub process is problem definition and data collection and the second is text knowledge mining. With reference to the problem we need to identify what kind of problems we have in our hand that means what is the problem context. This research we are conducting qualitative based research where first we need to identify the problem and then based on the identified problem we have to perform the text knowledge mining.

1. Problem definition and Data Collection

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This is the first phase of public domain based requirement engineering to take the initiative in order to identify the root cause and clearly define the problem. This phase is very crucial because this is the starting point of our requirement engineering where we should collect the data from the social media posts or through web scraping to include the feedback and perception about the problem from various users or customers to identify the issue or problem. In this phase we have to decide what kind of data should be gathered or, what kind of knowledge should be mined. In this phase we have to decide what will be our data sources. The data source could be the social media data which has been posted by the different customer's, consumers or, it could be from the online news portal or web scraping can be done to collect the data from various websites. Additionally, data can be also gathered from the statistical center of the particular country. The output of this phase will be the input for the next phase that is text knowledge mining.

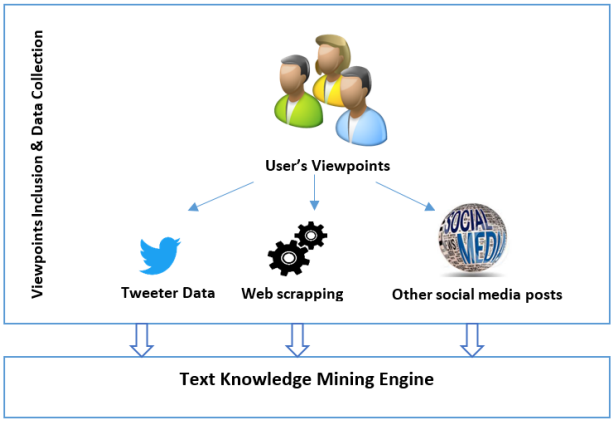

FIGURE 2:Viewpoints Inclusion and Data Collection

2. Root Cause Mining using Text Knowledge Mining

Root cause analysis is a popular method in Science and Engineering discipline, which helps us to identify the root cause of a fault or a problem. In this research it's an effort to modernize the root cause identification process in the light of data mining and web engineering. In this proposal text knowledge mining has been emphasized to identify the root cause of a problem. Text knowledge mining engine is responsible to acquire the knowledge from each piece of textual data, text knowledge mining is different from knowledge based system, unlike the knowledge based system in text knowledge mining each piece of text will be processed in search of the facts which we are looking for as a root cause of the particular issue or failure, it is not necessary each piece of text is having the content which we are looking.

TKM is an innovative technique to acquire the new knowledge from the semantic text by implementing deductive and/or abductive inference, where TKM applies inductive inference. [17]TKM intends to mine the knowledge by using the knowledge content found in the given text. TKM is a refined process to find the knowledge using reasoning from the existing knowledge that exists in the given text. This technique is well suited to perform the root cause analysis to know the cause of a particular incidence.

Let's deep dive into text knowledge mining, in text knowledge mining the knowledge is managed by the system which is purely based on the collected text and each statement in the textual data is representing a piece of knowledge which can be utilized for the detail reasoning to understand the root cause of a particular problem in order to solve a specific issue.Text knowledge mining is similar to knowledge based system but in reality it is not, in knowledge

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based system the base is constructed by containing the knowledge which is required by the system to resolve a particular issue but in knowledge text mining each of the text is not necessary that its addressing the knowledge which is required to solve a particular issue, in this context knowledge text processes the large amount of textual data and the text developer or the natural language processing developers need to apply the custom logic to filter out the knowledge through the reasoning process which is expected and required to resolve a particular problem. Knowledge text mining is well-suited to perform the root cause analysis.

Key challenges of Text Knowledge Mining:

a. The text knowledge mining should we perform in such a way which is responsible to provide new findings which is previously completely unknown but into a particular problem context it is potentially required and ultimately useful, all such pieces of facts or, knowledge will be gained by the applying custom logic using appropriate data mining techniques on the collected textual data.

b. Knowledge based system is responsible to answer the each query which is submitted to the system but in knowledge text mining there will be no specific question for which text knowledge mining based application is responsible to answer instead text knowledge mining based system is expected to find a new knowledge this knowledge could be the fact about particular events, the cause or questions are anonymous at the beginning of the process and as result it should be known as a actionable insights. [16]

Text Knowledge Mining Process Overview:

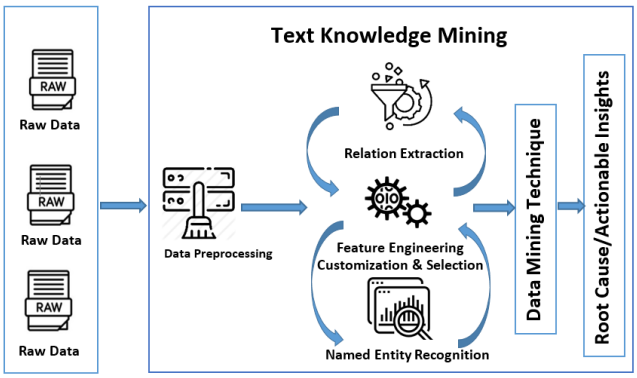

FIGURE 3.Text Knowledge mining

Text knowledge mining is the second phase of public domain based IoT requirement engineering process in the first phase of requirement engineering process we have collected the data from the various sources with consideration of different users' viewpoints. The output of the first stage will be the input for the second stage. As illustrated in the diagram the starting point of this phase is the raw data. Raw data will be passed for the preprocessing of the data which includes data scrubbing and transformation. When the data will be preprocessed it is fit for

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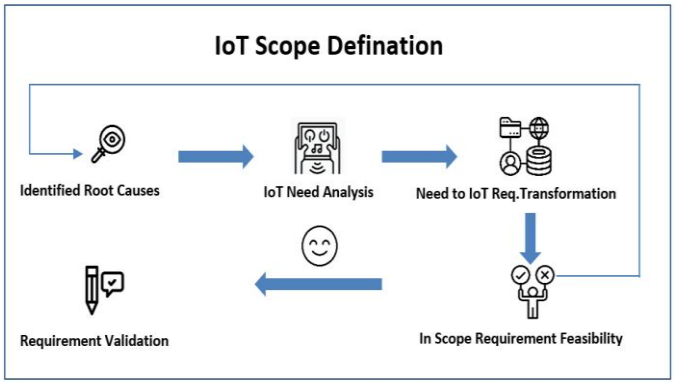
conducting the feature engineering which intent to convert unstructured data into a structured format [18]. Feature engineering will be customized into two aspects, the first one is relation extraction and second is named entity recognition where relation extraction is responsible to establish the relationship between the two or more conceptual text on another hand entity recognition is responsible to identify the noun keywords such as a country name, object, equipment or, instrument etc. in addition to that feature engineering customization process will try to establish a connection between the name entity and the conceptual words which has been found during the relation extraction and finally feature selection will be takes place to construct a quality structure textual data which will be well suited to apply any data mining techniques such as classification, clustering etc. with respect to the selection of data mining techniques is purely depending upon the problem context. After the successful implementation of the data mining techniques and algorithm system will produce the actionable insights or the root cause if the requirement engineering process has been carried out with the intention to find out the root cause of any accident or failure of a system.

3. IOT Scope Definition

This is the third process in the public domain based IOT requirement engineering. The output of "Text Knowledge Mining" is the input for this process. The aim of this process is to define the problem and stakeholders' needs based on the root cause and actionable insights. The following outcomes are produced after the successful execution of this process.

FIGURE 4.IOT Scope definition



a) Identification, analysis and detailing the problem

After completion of text knowledge mining the paradigm will throw the root cause or the actionable insight as a result. So, based on root causes researchers or the engineers need to analyze the root cause of the particular event in order to deal with the problem.

b) Identification of stakeholders and defining the stakeholders' needs

In this sub-process, needs stakeholders will be identified and needs of stakeholders should be clearly defined in order to resolve the particular issue.

c) Transformation of stakeholders' needs into requirements/ goals

Once the needs will be defined then we can transform them in the form of requirements and it can be defined as a goal to achieve.

d) Validation of stakeholder's requirements/goals

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In this sub process need to validate the system requirement and the system goal. This is the last sub process of the scope definition where all the requirements and the overall goal should be checked minutely. In addition to that, we need to ensure the feasibility to implement the defined requirements within the scope of the proposed system.

4. IOT System definition and functional Requirement

This is the fourth process in the public domain based IOT requirement engineering. The output of "IOT Scope Definition" is the input for this process. The aim of this process is to define IOT scenarios and specify IOT components. The following outcomes are produced after the successful execution of this process.

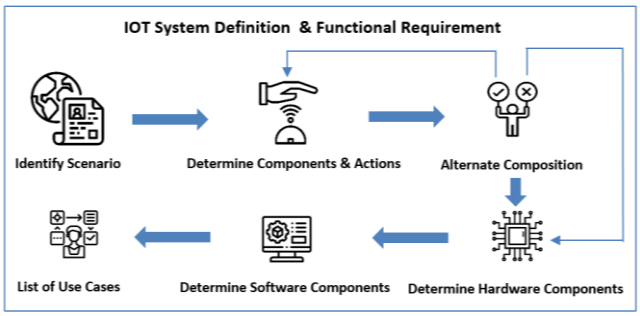

FIGURE 5. IOT System Definition & Functional requirement

a) Identify Scenarios

This is the first sub-process of the IoT system definition and functional requirement under this sub-process we need to define the individual scenarios. Scenarios will be defined based on the scope and the overall system goal which has been defined in the previous stage.

b) Determine Components and Actions

In this process we need to trace the scenarios which have been defined previously and based on the scenarios we need to identify the components which will be required to develop the IoT device. These components could be sensors and microcontrollers such as Arduino or Raspberry Pi etc. as per the suitability of the identified requirements.

c) Alternative composition

In this stage alternative compositions will be identified, for instance there are many alternative sensors available to measure the hits and alternative sensors should be identified. Alternative microprocessors also can be identified. However compatibility with the selected sensors and the microprocessor should be checked.

d) Determine Hardware components

In this stage hardware components should be determined based on the identified scenarios, determined components and actions.

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e) Determine Software components

In this stage the software component should be determined. The selection of the software components or tools must be in line with the hardware components which are already determined in the previous stage. As an outcome of this stage should be a platform where all the connected hardware components are controlled by the return code.

f) List of Use Cases

In this stage use cases should be described in order to get the expected actionable insights with the logical sequence of steps. To achieve the overall goal of the proposed system should be shown in the form of use cases or in another word applicability of the system should be clearly known by referring to this list of use cases.

5. Requirement traceability and Verification

This is the final process in the public domain based IOT requirement engineering. The output of "IOT System definition and functional requirement" is the input for this process. The aim of this process is to verify the functional requirements. The following outcomes are produced after the successful execution of this process.

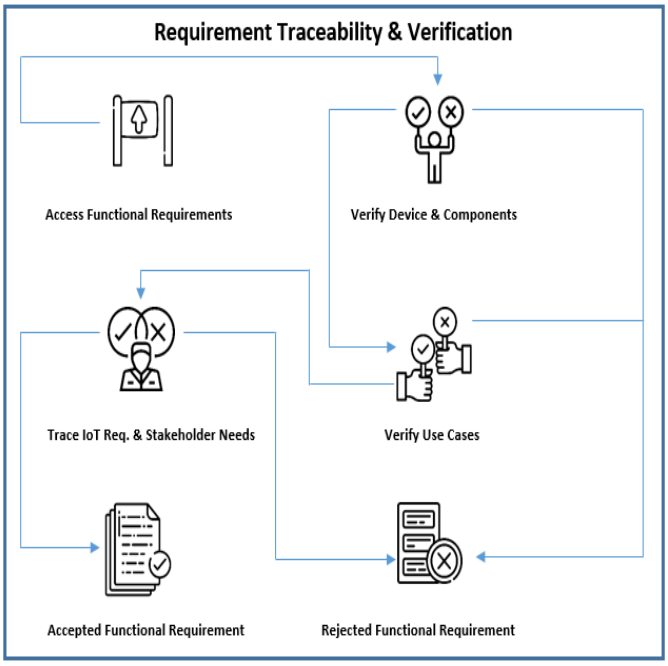

FIGURE 6. Requirement Traceability and verification

a) Verification of hardware and software components

In this state hardware and software components should be verified by checking the actual output of the connected components with the expected output from each of them.

b) Verification of Use cases

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In this stage constructed use cases should be verified with the expected applicability of the application.

c) **Traceability of stakeholder requirements to IoT system requirements specification is developed.**

In this stage, trace the stakeholder's requirements which have been acquired in the previous stage by executing the Root Cause Mining process. In fact, the stakeholder's requirement that we have gathered while implementing the Root Cause Miningshould be mapped with the constructed use cases. [16]

v. Research questions

ID	Research Questions	Rationale
RQ 1	What are the problem domains covered in the proposed RE framework?	The proposed framework can be deployed to satisfy the need of the requirement engineering process when we are required to identify the problem from the reasons extracted from the multiple source and finally root cause will be achieved as actionable insights to proceed further development of the application.
RQ 2	What are the approaches and techniques used in proposed RE within the IOT context?	The novelty of this proposed framework is the incorporation of new concept called root cause mining and the requirement engineering process for IoT devices. To extend that there are five phases and the RCM process is one of them. Achieving the root cause mining is a novel approach where inductive or deductive approaches can be opted. As a broad category natural language processing and all its relevant techniques can be utilized in order to find out insights as root causes. The techniques like text knowledge mining, text mining or even opinion mining can be modified by implementing the available algorithm and techniques to form it as a root cause mining.
RQ 3	Which type of evaluation or validation strategies are applied to proposed RE?	We have evaluated and validated our proposed RE framework by comparing the existing requirement engineering phases and techniques to develop specific IoT devices.
RQ 4	Why have traditional requirement elicitation techniques been replaced	The existing requirement elicitation techniques to understand the system and make a list of the

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	with RCM in the overall RE process?	requirements was not capable of resolving problems. The list of requirements should be derived aftercarefully investigating the root cause of the failure in order to take the preventive measures. RCM is a unique approach, it is a blend of natural language processing and the root cause analysis.
RQ 5	How is the Root Cause Analysis and Root Cause Mining is different in nature and technicality?	Root cause analysis and root cause mining both are conceptually the same. Technically they are different, root causeanalysis is a traditional technique where we are finding out the reasons by applying our manual analytical skills by taking the help of notation based IT tools on another hand root cause mining will be utilizing the techniques, algorithm and approaches of Natural Language Processing/Text Knowledge Mining.
RQ 6	Is the proposed RE in collaboration with RCM and can handle all the IOT based RE process?	No, the proposed requirement engineering process by blending root cause mining cannot fit for all kinds of IOT requirement engineering. The proposed framework will suit only when we need to transform the root causes as a list of requirements for the further development.

VI. Conclusion and Future Work

This paper proposed requirement engineering Framework in collaboration with a novel concept called root cause mining. The Framework is intended to facilitate the requirement engineering process for IoT devices where we need to transform the root causes as a list of functional requirements and detailed use case scenarios that are used for the further development of an IoT based application. The root causes can be acquired by implementing the web mining or any data ingestion tools to collect the data from various sources and process them by using natural language processing or text knowledge mining.

In futurework, we have planned to deploy this framework and build a IOT based device. Later we will compare physical result and the expected result in terms of the accuracy in preventing the accidental

events such as building an IOT device to prevent the electric fire in any residential or commercial buildings.

ACKNOWLEDGMENT

ISSN: 2005-4262 IJGDC

We would like to convey our thanks to The Research Council (TRC) of Oman for funding the research project titled as "*Unifying Requirement Engineering, Machine Learning and Opinion Mining to Implement IOT Solutions: An Effort to Reduce Electrical Fire and Casualties in OMAN*". (Project Id: BFP/RGP/ICT/18/082) and Dr. KhalifaZayid Al Shaqsi, Chairman, Research and Consultancy Committee of UTAS-Nizwa for his continuous support and guidance.Additionally, we would like to thank to Mr. T V Sathyanarayana, Dr. Sanjay, Dr. Chaitali and Mr. anwarfor assisting in this research.

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