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A novel approach to elicit distributed requirements for IOT system using SVM classifier

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Abstract: Internet of Things (IoT) is one of the growing technologies embedded in most application systems. It aims to solve real-world problems in different environmental fields such as industry, education, healthcare etc. IoT is becoming an integral part of daily devices and technologies opening a need for efficient and novel solutions to meet functional requirements that are more complex than those in traditional requirement engineering (RE). In addition, remotely smart systems present new challenges and lack in RE process that needs a solution. IoT systems open new research issues in RE such as elicitation, analysis, specification and management of IoT RE. To solve this lack of RE new smart techniques based on AI must be applied in the elicitation RE process. This paper presents a new smart dynamic approach in the RE elicitation phase to build dynamic functional requirements based on AI models. New stakeholder expectation needs from the smart IOT system are collected and stored in the requirements dataset. These new requirements are analyzed and classified into requirement features using the Support Vector Machine classifier. These classified functional requirements are compared to the IoT system, and the positive training requirements are added to the smart functional requirement presented in the IoT system. The proposed approach shows a significant accuracy of 95.64%, where 395 features were classified and detected from 413 entered features. This paper measures the gap between stakeholder expectations and device requirements in smart systems; these proposed measures can be implemented to optimize smart device specifications for manufacturers.
Keywords: *IoT, IoT-requirements, Requirement classification, Requirement engineering.*

1. Introduction

The Internet of Things (IoT) is a rapidly growth technology that used in different aspects of modern society, including business, education, manufacturing, governments and many other sites in society. The rapid changes in the technology influenced the automation systems to be smarter to use the surrounding devices around the user under what's called IoT. Increasingly, most systems in a variety of fields are using IoT to operate more efficiently, but these systems need better understand for customer requirements to deliver the optimal customer service and to improve decision-making for business needs. The Internet of things (IoT) is a set of physical things or objects that communicate and interact by employing internet over devices, sensors and software systems to be smart. IoT used in different technologies and fields of our life such as vehicles, home devices, and smart cites education, logistics and other objects embedded with electronics that are connected to software. Smart devices in IoT systems have the capability to collect, exchange and analyze data within the IoT systems over the communications networks or the internet [1][2][3][4][5].

Furthermore, IoT systems and devices must be more smart, effective, and available readily to respond for interconnected critical system such as: healthcare systems [6], COVID-19 pandemic management [7]), robotics [8], image recognition [9–11], and agriculture [12].

IoT systems deal with transmitted information to be accessible by the user at any time form any place over the internet [13].

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The IoT concept is emerging rapidly to produce new system solutions for multi purposes. This rapid evolution of using IoT systems led to a lack of optimal user requirements where an IoT system is vary relative to different devices and software used in IoT systems. Therefore, users most likely have distinct needs, and IoT systems should be able to deal with these distinct needs through a detailed requirements engineering (RE) phase for functional (FR) and non-functional requirements (NFRs). [14]. RE is a sub-discipline of software engineering (SE) that deals with software goals, functionality, and constraints even for hardware and software system requirements [15]. In addition, RE identify the user needs through requirements analysis, specification, and validation [16, 33]. However, RE is very important to produce systems that satisfy the customer's needs and expectations. Nowadays, there is an urgent need to implement IoT systems with efficient and well-planned functional and nonfunctional requirements to satisfy the user goals and satisfaction. Furthermore, implementing the RE for IoT has great challenges in real world complexity. Furthermore, developing reliable systems with essential needs that satisfy user expectations of system requirements are highly interconnected [17].

In this work we present a new approach to elicit RE for IoT devices various IoT user needs using SVM classifier to classify the most frequently used requirements and to add new requirements based on user expectations compared with smart device functionality.

This paper provides an approach to elicit software requirements for IoT systems using intelligent technique based on arterial intelligent methods using SVM classifier. The paper is organized as follows. Section 2 provides an overview of the current state of IoT requirements elicitation techniques used in IoT systems. Section 3 discussed the methodology and the proposed work Section 4 presents a smart approach to elicit requirements and build a dataset for IoT devices in the smart system. Section 5 presents a smart approach to elicit requirements and build a dataset for user need in the smart system. Finally, section 6 the conclusion and discussion of the variance between the IoT requirements and the user requirements and provide some recommendations to match between what the IoT functionality and the user functionality needs.

2. Related Work

The rapid growth of manufacturing of multi-functional smart devices opens new challenges and lacks in RE process. New research areas in smart software engineering requirements need solutions to deal with the new requirements of IoT systems. May researchers proposed different aides and solutions but this research area still an open research filed for the new expectations of IoT systems.

Despite the increased of RE complexity for both functional and nonfunctional requirements for IoT system and the rapid growth manufacturing of smart multi-function devices, many authors have addressed some challenges.

In [18], the authors present a tailored and harmonized definition method of a requirements engineering process for IoT systems. This definition process compound set of RE processes of ISO IEC/IEEE for the needs of IoT systems such as Stakeholder Needs, System/Software requirements definition process, business or mission Analysis process. They defined, identified potential stakeholders and their needs, analyzed the detail problem and find the stakeholder requirements. Then they defined IoT scenarios, components, actions, identified alternative arrangements and select the preferred arrangements.

Laplante et al. [19] proposed a RE process for eliciting requirements for emergence room activities in IoT system. The proposed approach use rich pictures for modeling the system using informal rules and use cases.

[14] The authors presented a review study of IoT systems based on systematic mapping study (SMS) methodology that used parametric on existing literature in medical field that has been implemented in software engineering (SE). they classified the research in RE proposals that used in IoT software systems. The proposed work used to improve the quality of development of IoT systems. They found that 132,327 articles in the literature were obtained from essential scientific data sources. And only 24 articles were studied in depth. These numbers clearly show that RE not been well-defined and created to development of IoT systems.

Some researchers focus on measuring usability for smart classroom models and technologies, and data management the arrangement related to inside and outside of classrooms. In [20] the authors proposed a new Multimodal Learning Analytics (MMLA) architecture using virtualization principles based on defined software and network function. They can scale solve some problems such as deploy, reconfigure, and dismantle using MMLA. In addition, they measure the performance and feasibility in different devices in the smart classroom.

Authors in [21, 36] proposed an intelligent requirements elicitation model for functional requirements based converting requirements into features and saved on dataset to be used by SVM classifier to decide if the requirement is one of the operational functions of the system.

In [22] they proposed a web service-based IoT framework using fuzzy logic arrange the resource subtasks from mobile to cloud services such as edge cloud, Arduino. The implemented services used to store and analyze the classroom lectures and shows saving in resources energy, bandwidth, and execution time and increase mobile resources the offloading subtasks from mobile to cloud services.

The researchers in [23] presented a new dynamic model for automated requirements engineering process. They save the collected requirement into a table format to be analyzed and normalized by eliminate the duplicated requirements. The table standard requirements used to generate a documentation template automatically. More research presented about eliciting requirements were presented in [24][25].

The authors in [26] proposed an extended agent-oriented approach based on ACOSO (Agent-based Cooperating Smart Objects). They used requirement engineering elicitation, analysis, and specification phases to analyze, design, and implement smart dynamic IoT system. They used a multi-agent system to develop complex IoT system for University Campus. Many researchers in [27, 28, 29, 30, 34 and 35] they used different classifiers to elicit system requirements. Furthermore, many researchers present different models and techniques in IoT requirements elicitations systems. Besides that, a recent research in [40] presented by the same authors about the main headlines in a novel approach to elicited IoT requirements of multi-functional smart devices that are distributed in deferent locations, where this paper extends the methodology with technical and experimental issues.

3. Methodology

Figure 1 shows a high-level architecture of the smart room application.

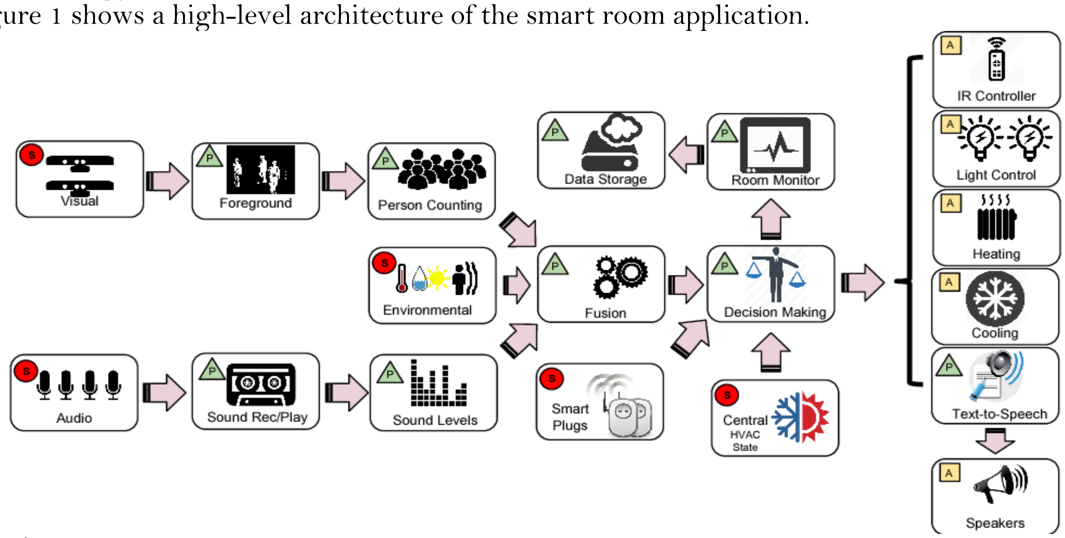

Figure 1.
High-level architecture of the smart room application [31].

IoT system devices must be integrated over hardware devices, communication, I/O data management, software requirements and software interface. In order to build effective and efficient system, general and specific requirements must be defined [32].

In IoT systems the functional requirements always built by the manufacturer to do specific functionality. While the system stakeholder needs may be different from the device functionality this makes gab in smart system requirements to reach an optimal software solution.

To investigate the effectiveness and compatibility between the IoT presented requirements and requirements of stakeholder needs from IoT smart systems the methodology will be conducted in three phases:

3.1. Elicitation of Functional Requirement presented by the IoT Smart Devices

In this paper, we proposed a new approach to elicit functional requirements for IoT systems. The available actions and functions of smart devices in IoT system will be collected and stored in Internet of Things Functional Feature Requirements Dataset (IOTFFRDS). Furthermore, the IOTFFRDS dataset for the smart devices contains multi functions for each device in the system. The functional requirements elicited from the IOT system devices are illustrated as the following:

- Create a table contains IOT devices as: device Id, device name, device location and device description (DNLDT) as shown in Table 1. This table can dynamically contains any number of devices with its attribute columns

Table 1.
Device name and description (DNLDT).

Device Id (DID)	**Device name (DN)**	**Device location (DL)**	**Device description (DD)**
1	IR Controller	Classroom 237 2nd floor	Control the data show & Air conditions

- Create the device functional requirement statements of the IOT system devices, keywords and features dataset (DFRSKFD). This table includes the device name (DNAM), the functional requirement statements (RS) of smart device, the requirement keywords (RK) and the requirement features (RF) as shown in Table 2. Each device name has many functional requirement statements each with relative functional keywords and set of features.
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Table 2.
Device functional requirement statements, keywords and features (DFRSKFD).

Device name (DN)	**Device functional requirement statement (DFRS)**	**Device requirement keywords (DRK)**	**Device requirement features (DRF)**
		DRk1, DRk2, DRk3, … DRkn	DRf1, DRf2, DRf3,… DRfn

We considered that these two tables are created by expert users and contains all smart device available functionalities that are tested and trained by expert users. This dataset table will be used as the trained dataset for all available requirements in the IOT system devices. This trained dataset well be used in evaluation process to compare with the stakeholder requirement needs.

3.2. Elicitation of Functional Requirement Needs for IoT System Stakeholders

In the second phase, the system functional requirements for all users will be collected and stored in Stakeholders Functional Requirements keywords and Features Dataset (SFRKFD). The SFRKFD datasets contains the user needs, and feature keywords for each analyzed requirement. The functional requirements elicited from the IOT system stakeholders are illustrated as the following:

- Create the functional requirement statements of the IOT system stakeholders, keywords and features table (SFRKFD). This table includes the stakeholder functional requirement statements (SFRS), the stakeholder requirement keywords (SRK) and the stakeholder requirement features (SRF) as shown in Table 3. Each functional requirement statement has a set of functional keywords and set of features.

Table 3.
Stakeholder functional requirement statements, keywords and features (SFRKFD).

Stakeholder functional requirement statement (SFRS)	**Stakeholder requirement keywords (SRK)**	**Stakeholder requirement features (SRF)**
	SRk1, SRk2, SRk3, … SRkn	SRf1, SRf2, SRf3,… SRfn

This table is created by expert users and developers to be used as the trained dataset for all available requirements of stakeholder s in the IOT systems. In addition, this trained dataset well be used in evaluation process to compare with the IoT device requirement.

3.3. Converting Requirement Statements to A Set of Keywords and Features

In this algorithm the stakeholders and the devices requirement statements are converted into set of requirement keywords and features. The functional keywords are extracted by scanning the requirements statements using the proposed dataset in Section 3.1 and 3.2. The support vector machine (SVM) classifier is used to detect the functional keyword existence in the trained requirement keywords dataset. The proposed algorithms are illustrated as below.

Algorithm 1: Convert requirement statements into set of keywords and features

1- Open DNLDT, DFRSKFD and SFRKFD dataset tables.
2- Insert and save the device id, name, location and description in DNLDT table.
3- Read the requirement statement (DRS and SRS).
- *Correct the requirement statement (detection errors).*
- *Split the requirement statement into sentences based on (.) dot punctuation mark and remove stop characters by using the general architecture for text engineering (GATE) [37].*
- *Extract the words in each DRS and SRS based on tokenization, sentence splitting and stemming, as shown in classifier design in Figure 2.*
- *Normalize the table of keywords to remove the redundancy.*

4- For each entered DRS and SRS, search for each word in the text using the proposed detection algorithm (2) using SVM classifier to find the accepted features in the trained functional keywords datasets:
If (the extracted features exist in the Trained DRS or SRS)
{a. Modify the accepted class.
b. Select the correct subclass functional features.
c. Select the highest accepted subclasses matching the input keyword and features.
d. Find out the accepted keyword commands to the Smart device in the IOT system. }
Else
{Skip to next requirements statement to find keywords and features.}
5- Repeat steps 3 and 4 until all entered requirement statement finished.

To find the entered keywords and features, we use an intelligent approach that classifying and detecting the most acceptance trained class or subclass to the input stakeholder requirement statement based on the trained dataset SRS, DRS. This method uses SVM classifier for Detecting and Classifying the Functional Features and keywords as in algorithm 2.

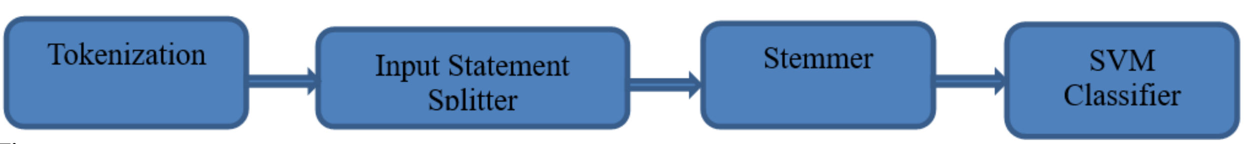


Figure 2.
Design classifier to extract words and features.

Algorithm 2: SVM classifier for Detecting and Classifying the Functional Features and keywords

a- *Use the trained dataset in step3 to classify the input requirement using the SVM classifier.*
b- *Scan the input requirement keywords into set of structured features using the approach proposed in [38].*
c- *Classify the resulted keywords into classes and subclasses using SVM classifier.*
d- *Find the highest accepted classes and subclasses that satisfying the most suitable keyword to the inserted statement.*
e- *Loop from step (a) to step (d) until end of DRS and SRS.*

These feature keywords for both Stakeholder and Smart devices are stored as training dataset with feature keywords that can be used by the classifier. This dataset will be used in the requirement analysis phase to verify the functional requirements for used need, expectation needs, and device functionality. In addition, this dataset will be used to find the ratio of stakeholder needs relative to smart device functionally by using classification and evaluation of the inserted requirements from the user. The proposed methodology contains the training dataset phase for collected requirements for both stakeholder and smart device and the testing phase are illustrated as below:

The training phase for system stakeholder requirements and expectation requirements:

1. Find feature keyword requirements from stakeholders.
2. Generate User-dataset table of requirement feature keywords.
3. Generate the training dataset for all stakeholder requirements.

The training phase for smart device requirements:

1. Find feature keyword requirements available in smart device.
2. Generate smart-dataset table for available smart feature keywords.
3. Generate the training dataset for all smart devices requirements.

The testing phase:

1. Input user requirement action
2. Find feature keywords.
3. Classify and evaluate feature keywords using the trained dataset using SVM classifier to find availability ratio.

The methodology and the proposed model are shown in Figure 3 A & B.

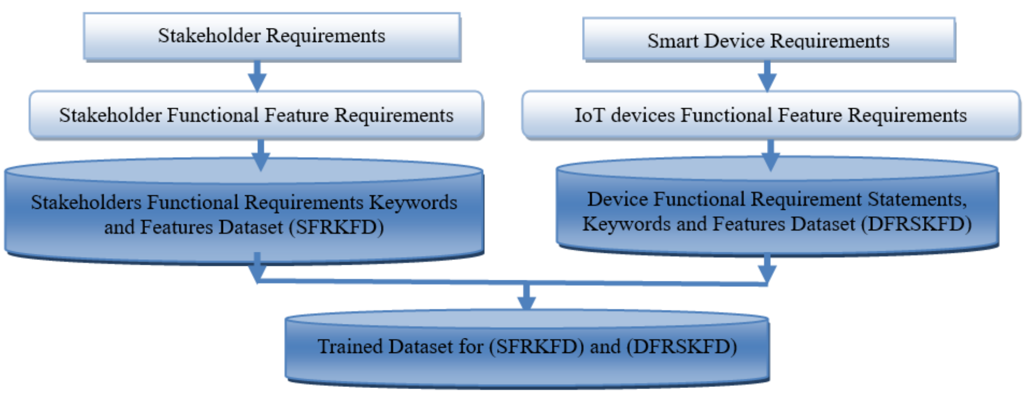
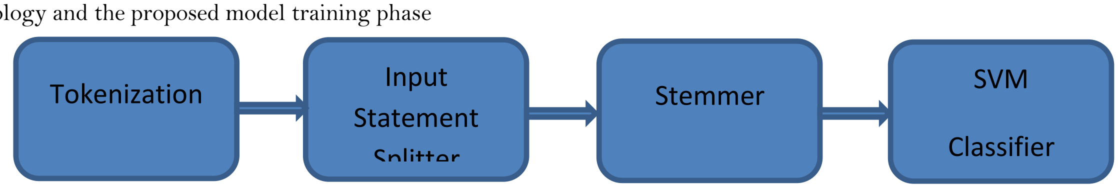


Figure 3 (A).
The methodology and the proposed model training phase



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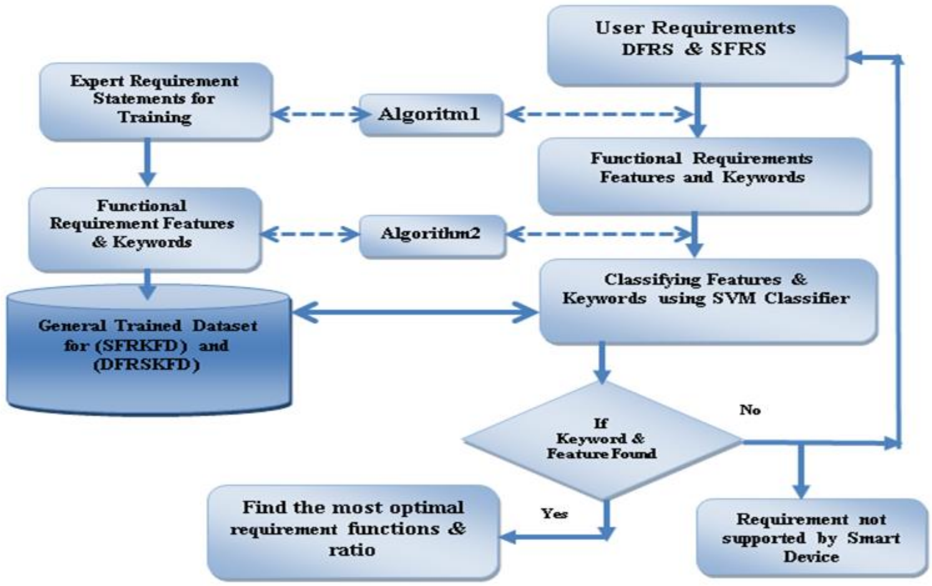

Figure 4 (B).
The methodology and the proposed model for testing phase.

4. IoT Data Collection and Analysis

The requirements data is collected from different smart devices and different system stakeholders. Various methods are used to collect requirements data such as: surveys, interviews, observations, and performance assessments for both smart devices and stakeholders. The collected data was analyzed using many techniques such as qualitative and quantitative relative to the nature of the collected requirements.

The results in Table 4 show the tested classes from class 1 (C1) to class 12 (C12) of the input extracted keywords and features based on training dataset using SVM classifier. The result class will be the most intelligent optimal solution for the user needs in the IoT system of the smart devices. The SVM classifier is evaluated based on the tested requirements using 6 user requirements over 4 multi-functional smart devices on 6 different labs and classrooms. The results are evaluated using the metrics of Precision, Recall and F-Measure [39], defined as follows:

$$\text{Precision} = \frac{\text{TP}}{TP+FP} \qquad \text{Recall} = \frac{\text{TP}}{TP+FN} \qquad \text{F-Measure} = \frac{\text{2 x Precision x Recall}}{\text{Precision}+Recall}$$

Where, TP (True Positive) is the number of correctly classified requirements, FP (False Positive) the number of requirements incorrectly classified, and FN (False Negative) the number of requirements incorrectly not classified.

Table 4.
The results of testing phase of requirement keywords and features of IoT System.

Number of smart devices	Number of keywords & features	Number of classifier keywords & features	Requirement statements of feature classes (C1 … to C12) ratio %
5	63	61	96.83%
5	77	75	97.40%
5	108	103	95.37%
5	92	86	93.48%
5	73	70	95.89%
Total	413	395	95.64%

Source: The overall testing phase results of the classification process using SVM classifier show significant accuracy of 95.64%, where 395 features were classified and detected from 413 entered features.

5. Evaluation Results and Remarks

May devices with multi functions are used in many experiments by more than one user with different requirements and needs in the IoT system. The user expectations from the smart devices in IoT system are performed. The experiments were done in distributed rooms that contain different smart devices with different functionality. The proposed work was implemented by using Asp.net C# in a Core i7 with 6GB of RAM. The proposed work show significant accuracy 95.64% using SVM classifier in requirements elicitation for IoT system.

In addition, we compare between user expectation requirements with what the device do based on its configuration requirements, where the experimental results show that 19.6% of the smart devices functionality not used or expected by the user. Other experimental results show that 23.7% of the user expectations requirements are not configured or not available in the smart device functionality. These results can take inconsideration to improve and enhance the functionality of smart devices in IoT system to satisfy the user expectations. In addition, open a new research filed in IOT systems to compare the user needs and expectations to the smart devices functionalities.

6. Conclusion

The proposed technique will help the developers of IoT systems to identify the functional requirements available by the smart devices in the IoT systems and decide if the user need found or not. In addition, it can be used to improve the smart devices functionality based on the expected need of the users that are not found by the device. The proposed technique can manage the requirements of may smart devices with multi functionally and multi user requirements. In addition, the proposed technique shows significant results that can be used as statistical information for the IoT system requirements ratio with user needs.

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