An ANFIS-Based Compatibility Scorecard for IoT Integration in Websites

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Abstract: Cyber Physical systems (CPS) and Internet of Things (IoT) form two different levels of the vertical digital integration. Integration of websites with IoT connected devices has compelled creation of new web design and development strategies where websites are designed keeping in mind the permutations of smart devices. The design should be seamless across different devices and the website design company or web designer should be well-informed and aware of the different considerations for design with IoT interactions. In this work, we expound the effectiveness of IoT integration in website design. To realize an IoT-powered IT ecosystem as an essential technology for improving customer experience a SWOT (Strength-Weakness-Opportunity-Threat) analysis is done. Further, with an intent to apprehend the integration support that an existing GUI front-end may provide to a smart device, an ANFIS model is proposed to determine the compatibility of an e-commerce website for integration with IoT devices. A dataset of 600 e-commerce websites from .com domain is used to train and test the learning model. Seven features (page loading speed, broken links, browser compatibility, resolution, total size, privacy and security, interface and typography) which impact the compatibility of IoT integration in websites have been used. Evaluation criteria for assigning score to each feature has been identified. Finally, the compatibility score, the $IoTScore_{site}$ which evaluates the websites' integration capabilities and support to IoT devices is generated by adding all the feature scores. The preliminary results generated using the prediction model clearly determine the worthiness of website for IoT integration.

Keywords: IoT integration, website design, cyber physical systems, ANFIS, machine learning

1. Introduction

An IoT is a network of objects embedded with electronics, software, network connectivity and sensors [1]. It is about connecting numerous heterogeneous cyber-physical devices or things that sense, monitor, analyse and adapt stochastic events gathered without human origination to create value from autonomic agents that process data to create granular knowledge and wisdom to support enable both machines or humans to make smarter decisions and actions [2]. It merges the virtual and physical worlds, creating a smart environment such that when these devices share and analyse data, they have the capability to transform our lives in innumerable ways. Fig. 1 explains how IoT and CPS are connected.

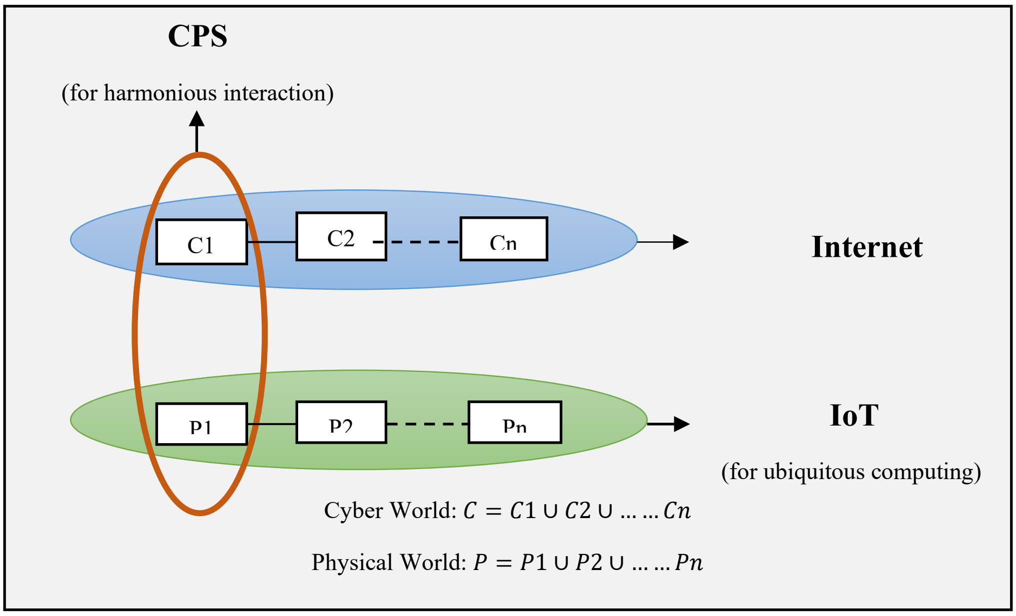


Fig.1. Interconnection between IoT and CPS

A generic IoT system involves three key components:

1) ***Embedded systems***: Consists of heterogeneous sensors responsible for providing information about the physical entity.
2) ***Middleware:*** Is responsible for data aggregation, acquisition control and network connectivity.
3) ***Cloud services:*** Provides comprehensive storage, computation, analytics, application hosting and management mechanisms.

IoT is a biggest frontier which can improve our lives in many aspects. This cutting-edge technology not only affects the consumers but also the providers of IoT solutions. With the ubiquitous internet connectivity and bandwidth in abundance along with reduced cost of wearables and smart devices, the impact of the Internet of Things and technology in our lives is manifold and profound. IoT devices are becoming a part of the mainstream electronics culture [3]. According to Statista[1] the IoT market is expected to reach $457 billion by 2020. This is a phenomenal increase from just $194 billion in 2017.

As the IoT solutions define the new paradigm for customer-oriented digital experience, they are inevitably getting more complex and dynamic. The network-connected cyber-physical devices can communicate via standard protocols and share data in different environments via the intermediate gateway nodes like modems, routers, switches, and cellular base stations. To build a single communication platform which acts seamlessly for devices and applications to talk to each other, regardless of how they are physically connected is a challenging task [4]. Developing a completely new platform of communication where all devices are digitally augmented is expensive and time-consuming. A better solution is to reuse the established World Wide Web ecosystem and leverage the capabilities of its readily available application layer protocol, thus typifying the concept of Web of Things (WoT). WoT complements the existing IoT ecosystems, reduces costs and creates value by combining multiple devices and information services [5,6]. More specifically, while IoT is all about creating a network of things, objects, people, applications and systems, WoT makes their integration to Web. Integration aids capturing data from smart devices and making the data move into business applications with the intent of automating processes, supporting real-time monitoring and applying analytics for understandings. Recently there have been many Web enabled IoT applications such as smart homes, smart cities, smart industry, smart agriculture, smart healthcare which play a significant role in our lives. Though, organizations and businesses are eager to develop applications that support these devices but exploiting IoT device interfaces to integrate applications with those devices can be complex. Further, deriving meaningful information is another crucial aspect.

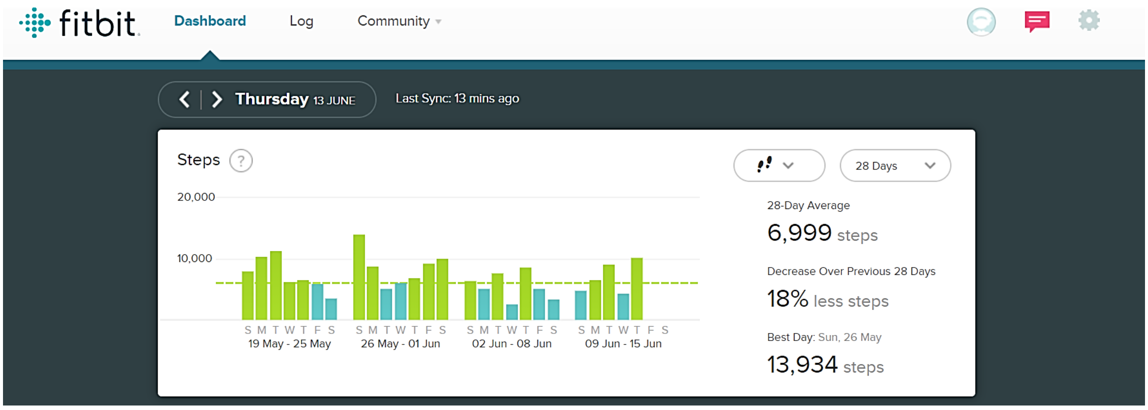
Web enabled IoT application development is a lot more intricate than a customary web development. This is primarily owing to the voluminous data, dynamic user interfaces, intense communications, and security and reliability problems pertaining to the IoT applications [7]. These peculiarities influence the current generation of website design and development. Web design can be broken into two key categories [8]:

1) Front-end: Graphical User Interface (GUI) which can be related to User Experience (UX) [9].
2) Back-end: Database storage, Data manipulation, and Data processing [10].

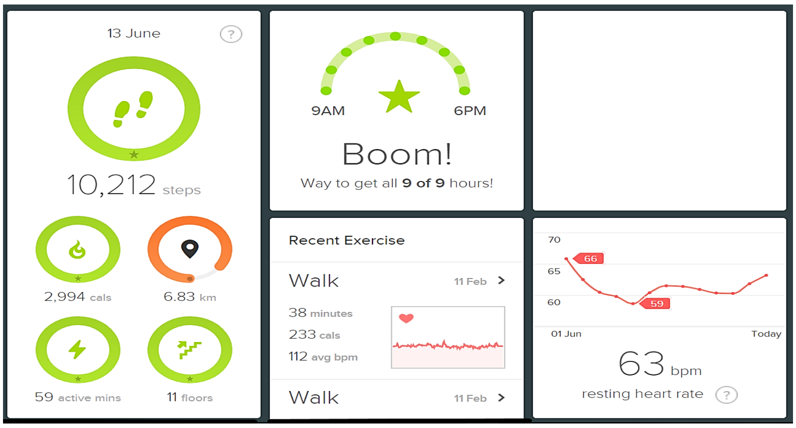
The front-end interface is used by the users to connect and communicate with IoT devices like cameras, sensors, etc. For example, the wearable technology, fitbit uses a bluetooth connectivity to track user's physical activity including the number of steps taken, distance traversed and calories

[1] Statista.com

burned, etc. [11] and integrates with software that logs this personal activity data (Fig.2). A clean interface is needed for an easy communication with smart devices. The design should be tractable and must adapt itself according to various IoT connected devices. Concurrently, numerous websites may also require the multifaceted capabilities to communicate with the back-end databases which store personalised data obtained from IoT devices [12, 13].



(a)



(b)

Fig.2. fitbit dashboard on "fitbit.com"; (a): User's physical activity tracked; (b): Personal activity log

The design should be seamless across different devices and the website design company or web designer should be aware and well-informed of the different considerations for design with IoT interactions. Thus, many challenges ascend for web designers in terms of both back end and front-end design to make a website worth for IoT integration. Some design considerations required to successfully develop website designs with IoT interactions include [14]:

- ***Strong back-end:*** It is important that communication between users & IoT devices is very clear. This can be attained establishing a robust back-end design architecture. Each of the devices has several capabilities, data, and commands that operate just according to the inclinations of users. A fine backend receives and transmits data, and it helps the users in communicating with the device in a seamless way.
- ***Intuitive User Interface:*** For an IoT application, it is vital to have a clean, fast and interactive layout. A web designer must work on latest web design practices, however, ensure that design inclusions are meaningful and should support rational workflow. Also, the major concern is that the new IoT based design should be mobile compatible so that smart users can benefit from it. User interface further requires to work on two aspects as given next:

    1) ***Easier Front-End Interaction:*** JavaScript is the most efficient language which has the potential to make a smart device interactive. It is an event-driven language and has capability of executing commands simultaneously with the interaction with smart devices, and capturing data in the databased. Moreover, it has the capability of multi-tasking where multiple tasks can run at the same time. JavaScript must be targeted by all web developers as it has an extensive set of plugins and libraries.
    2) ***Mobile User-Experience:*** Mobile interfaces are the need of today. Simple designs are better for understanding, and are easier to load on mobile. Web developers are expected to produce designs that are capable of adapting itself across many smartphone screens irrespective of the feature and size for the smart device.
- ***Speed Measurability:*** Conventional page requests are directly analysed by the web server. However, in the case of contemporary IoT integrated websites there are two hardware components, namely, the IoT device and web server using an internet cloud service, thus mounting the chances of slow user response and more latency. Thus, design strategies for slow connections must be adopted. Simple and lighter themes make the pages load faster. Following are some of the steps that can improve page load speed:
    1) Create AMP (Accelerated Mobile Pages) pages that are capable of loading faster on mobile devices.
    2) Use browser caching.
    3) Minimize the number of CSS and JS files.
    4) Reduce the number of redirects.
    5) Minimize the number of images.
    6) Hotlinking of images should be disabled.
    7) Reduce the server load with the use of CDN.
    8) Fix the broken links.
    9) Use caching plugins and clean the database.
- ***Power Management:*** Most of the IoT devices are battery-powered and wireless. For this, fully-fledged power management is essential. Heavy programmes running in the backend, do drain the battery and this leads to less user communication. This is why the new layout must be designed for minimising excess power use.
- ***Security & Privacy****:* One common drawback of IoT or the associated solutions is that they offer a way to hackers. If one could unlock a web-connected front door, a hacker potentially could do the same and help himself to the contents of the home. Though device designers are responsible for privacy and security, but there is a need of a third-party web designer who must make security the main design consideration.
- ***Testing Considerations:*** Testing of IoT integrated website is complicated than the conventional websites.

IoT has made a significant impact on E-commerce businesses. IoT-enabled devices exchange data with each other through the internet, helping retail and e-commerce businesses to carry on their operations efficiently. As more devices get connected and gain smart features, more data is gathered, and consumer experience is improved. With the penetration of IoT, the e-commerce industry will see a growth in revenue, a better supply chain management and inventory management and an improved customer service. This integration of websites with IoT devices has fostered the need to upgrade web design and development strategies where websites are designed keeping in mind the permutations of smart devices. Flexible, clean and user-friendly interface is the need of the hour where the information has to be displayed using lesser content

Motivated by this, in this work, we expound the effectiveness of IoT integration in website design and propose an adaptive neuro-fuzzy inference system (ANFIS) to determine the compatibility of an e-commerce website with IoT devices. The ANFIS combines the learning capabilities of neural networks with the abilities of fuzzy logic to model uncertainty in expressiveness. It incorporates the benefits of adaptive control technique, artificial neural network, and the fuzzy inference system [15]. The intent is to apprehend the integration support that an existing GUI front-end may provide to a smart device using a prediction model. A dataset of 600 e-commerce websites from .com domain is used to train and test the learning model. Seven features (page loading speed, broken links, browser compatibility, resolution, total size, privacy and security, interface and typography) which impact the compatibility of IoT integration in website have been used. These features have been derived from the design considerations for successful IoT interactions with website [14]. Evaluation criteria for assigning score to each feature is identified. The sum of all the feature scores generates the compatibility score, the $IoTScore_{site.}$ This compatibility score is finally used to evaluate the websites integration capabilities and support to IoT devices. Thus, the primary contributions of this research are:

1) A strength-weakness-opportunity-threat (SWOT) analysis to demonstrate the effectiveness of IoT integration in website design.
2) A novel ANFIS model to determine the compatibility of an e-commerce website for integration with IoT devices.

The proposed prediction model will facilitate to realize an IoT-powered IT ecosystem as an essential technology for improving customer experience. The paper is organized as follows: Review of related literature work is given in section 2 followed by section 3 which expounds the SWOT analysis of IoT integration in website design. Section 4 describes the concepts used in proposed model and section 5 presents the proposed ANFIS model. Section 6 discusses the results and finally, the conclusion and future scope of the research is presented in section 7.

2. Related Work

Various studies have been reported in the domain of IoT. Gubbi et al. [2] presented an implementation of IoT based on cloud vision and also discussed the application domains and technologies that were likely to drive IoT research in future. They have also presented an implementation using Aneka, which considered the interaction of private and public clouds. Lee et al. [16] presented five major IoT technologies which were important for the deployment of IoT-based products and services. The authors discussed three categories of IoT for enterprise applications used to enhance customer value and also described five technical and managerial challenges. Gigli et al. [17] introduced four categories of services which can be used to build an IoT application. Many applications of IoT have been reported in the field of healthcare and medical science [18, 19], agriculture [20], across fog and cloud [21] etc.

Software architectures originated from Web service research mainly for Web service interoperation to Web resources management for IoT have been proposed. Castellani et al. [22] worked on web services for IoT and concentrated on the communication technology for IoT devices and its implementation adopting the Representational State Transfer (REST) approach. The REST relied on GET and POST methods of HTTP and data was exchanged using standard XML. Xu et al. [18] proposed an IoT- based model for emergency medical services. They described the data collection, data integration and data interoperation methods in case of medical emergencies. They proposed a global data accessing method (UDA-IoT) to handle heterogeneous IoT data in medical service using RESTful architecture. Doukas et al. [19] discussed how IoT features web applications which can be accessed globally, were scalable, and were able to provide communication interfaces to peripheral applications. They discussed how appropriate interfaces enable the data dissemination to external applications. They also discussed how web apps provided the indispensable data real-time monitoring and management.

The authors also explained that device and location independence enabled users to operate the systems via web browser, and illustrated various websites which managed IoT sensors data. Yu et al. [23] argued that interactivity of a website is essential in IoT computer-mediated communications as it is considered as one of the key advantages of the medium. They also stated that interactivity is a vital part of the IoT service and influences customers' online experience in a positive way.

Researchers have proposed models which facilitate evaluation and assessment of websites based on various design features of the website. Kumar and Gupta [9] discussed the shift from software quality models to web based quality models eventually proposing a π model where the horizontal line of the π signified the backbone of quality models with quality assessment parameters common to both kind of software whereas the two vertical pillars of the π depicted the quality attributes specific to the software type. Loiacono et al. [24] proposed WebQual model which evaluated website quality based on a number of dimensions and the model was evaluated on three samples. Hartmann et al. [25] focused on user experience exploring some of the contextual features that impact user experience. Contextual evidence facilitate digging out user- centric information [26]. Sobecki et al. [27] demonstrated website usability assessment models and discuss about website interface quality. They also present models for organizing data in frames further to be used in an expert system. Schubert and Selz [28, 29] developed Web Assessment tool considering the three phases of a transaction on a website namely: information, agreement, and settlement and named this tool as WA. Extended Web Assessment Model (EWAM) was an extended model of WA which contained fundamentals of TAM and social influence proposed by Schubert et al. [30]. In our previous work [31], we identified website quality features which were necessary to predict the quality of website and introduced a website quality model using filter-wrapper based feature selection algorithms.

None of the above-mentioned website quality models consider integration with IoT to evaluate website quality. This research, is the first reported study to effectively capture and measure the IoT integration in websites qualitatively. We propose a prediction model to calculate an IoT integration compatibility scorecard for e-commerce websites. The study substantiates the need of IoT integration to collect data from smart devices to be utilized by the business applications to automate processes, support real-time monitoring, and apply analytics for insights. Thus, the proposed model is superlative as compared to other website assessment models [24-25, 27-30]. We propose an Adaptive Neuro Fuzzy Inference System (ANFIS) based model to validate the compatibility of IoT within a website. ANFIS has previously been applied in other areas of predictive learning which include image processing, face detection systems, etc. [32-34].

3. SWOT Analysis

A SWOT analysis framework is generally used by business organizations as a strategic planning technique for analysing relevant internal and external factors making an impact over people, process, product, projects, initiatives, objectives, and outcome of a system. It is a fundamental model used to evaluate the organizations internal strengths and weaknesses, as well as external opportunities and threats. It also acts as a vigorous mechanism for decision making [35].

Integrating websites with IoT connected devices brings the opportunity to adopt new front-end design strategies of websites. Sophisticated, flexible and a clean user interface is imperative. To examine how IoT integration with websites has affected the website design a SWOT analysis is done. The strengths, weaknesses, opportunities, and threats of IoT integration in Website design are as follows:

- ***Strengths:*** Strengths determine the internal, positive attributes of integrating websites with IoT devices.

- Innovative front-end web designs allow many IoT devices to display web data searched via browsers on the device's screen.
- Interactive user interface help users to interact with the websites on various IoT connected devices.
- New front-end web designs are mobile compatible that are used across various smartphone screens.
- New designs are being used which adapt themselves according to the varied screen sizes of IoT connected devices having different display types.
- New designs are capable of integrating with multiple web browsers which may be used to search web data on most of the IoT devices.

- ***Weaknesses:*** Weaknesses are negative factors that detract from the strengths discussed.
  - A single design may not be easy to adopt across different devices that are connected through IoT.
  - New website designs require the complex capability to communicate with back-end databases that are able to store personalised data obtained from IoT devices.
  - Due to communication and data transfer taking place through cloud slow user responses are experienced.
  - Heavy programmes running in the backend, use enough battery which leads to less user communication.
  - Testing IoT integrated websites is complicated than conventional websites.

- ***Opportunities:*** Opportunities are external factors that are likely to contribute to the success of the proposed model.
  - Avoid loss of productivity and loss of product.
  - Improved customer experience and engagement.
  - Increased competitiveness.
  - New revenue streams.

- ***Threats:*** Threats are external factors that cannot be controlled.
  - Designs for extremely small screen sizes are potentially difficult to be made.
  - As small screen sizes require web content without images which may not give desired e-satisfaction to users of websites.
  - Multi-device interaction mostly implies recurring authentications, gateway processes that differs with devices.
  - Security and Privacy may be breached when websites are integrated with IoT connected devices.

Quite clearly, creating a standardized setting for normal and seamless interactions between a user and a system is challenging. Adopting an IoT solution requires cross-functional coordination between business, operations and security verticals. Thus, based on the identified need to create efficient user experience for IoT products, in this research we assess the effectiveness of IoT integration in website design and propose an ANFIS to determine the compatibility of an e-commerce website with IoT devices. The ANFIS is trained using key features derived from the core design components supporting IoT integration with websites, namely, interactive interface, speed measurability, privacy and security and power management. The following sections discuss the details.

4. Background Concepts

The subsections 4.1 to 4.3 discuss the concepts and techniques used in this work.

4.1. Artificial Neural Networks (ANN)

ANNs imitates the human nervous system where number of nodes in ANN represents the neurons in brain [36]. The nodes are connected to each other by links which have weights associated with them. The nodes take data as input to perform basic operations on it and then pass the output to other nodes through connecting links. This output is known as activation value. The learning in ANNs takes place by updating weights of links whenever needed. Whether to alter the weight or not depends on the output predictions. In order to get accurate outputs, activation functions are applied on inputs. The most commonly used activation function in ANN is sigmoid function [37]. The way of modification of connection weights can be categorized as follows [38]:

- *Supervised Learning:* The ANN is given a dataset. The output of ANN is compared with the desired output present in the dataset. Based on the difference between predicted and actual values, the weights are updated. This process repeats until ANN gives the desired output.
- *Unsupervised Learning:* This way of training is independent. During training, ANN clusters the same kind of input data into clusters. For a new input data, ANN categorizes it into one of the clusters. No feedback on results is provided in this case.
- *Reinforcement Learning:* It is similar to supervised learning as in this case ANN gets feedback for its outputs. The difference is that here the feedback is evaluative instead of instructive. The weights are adjusted on the basis of these feedbacks.

There are two types of ANN topologies: feedback (feedback loops present) and feed-forward (unidirectional information flow, no feedback loops).

4.2. Fuzzy Inference System (FIS)

"A fuzzy Inference System abbreviated as FIS is a system that uses fuzzy set theory to map inputs to outputs". If intended to do fuzzy classification, the inputs are features and the outputs are the classes [39]. The process of fuzzy inference involves *membership functions, fuzzy logic operators,* and *IF-THEN rules* [40, 41].

4.2.1. Membership functions

Membership functions characterize fuzziness or the degree of truth in fuzzy logic. It represents a curve that describes the mapping between the points in the input space and membership values which are also called degree of membership. The value of degree of membership lie between the range of 0 and 1. The Fuzzy Logic Toolbox comprises of 11 types of built-in membership functions. These functions are built from some basic functions as:

1) piecewise linear functions,
2) quadratic and cubic polynomial curve,
3) sigmoid curve,
4) Gaussian distribution functions.

4.2.2. Fuzzy logic operators

Fuzzy logical reasoning is related to standard Boolean logic. Standard logical operations will hold when the fuzzy values are kept at boundaries like 0 (completely false), and 1 (completely true). In fuzzy logic, AND operator is implemented with minimum, OR operator is implemented using maximum and NOT as negation, i.e.

$$A\ AND\ B = Min(A, B) \tag{1}$$

$$A\ OR\ B = Max(A, B) \tag{2}$$

$$NOT\ A = 1 - A \tag{3}$$

4.2.3. IF-THEN rules

Usually the knowledge involved in fuzzy reasoning is expressed as rules. A fuzzy IF-THEN rule is of the form as given in equation 4.

$$IF\ Input_1\ is\ A_1\ AND\ Input_2\ is\ A_2 \ldots\ldots\ldots AND\ Input_n\ is\ A_n\ THEN\ Z = B \tag{4}$$

where, $Input_i$ and Z are fuzzy variables and A_i and B are fuzzy terms (fuzzy sets). The "IF" part is known as antecedent or premise, whereas the "THEN" part is termed as a consequence or conclusion. The inputs are connected via fuzzy logical connectives such as 'AND' and 'OR'.

4.3. Adaptive Neuro-Fuzzy Inference System (ANFIS)

ANFIS combines the best features of neural network and fuzzy inference system [42]. It is defined as a multilayer feed-forward architecture where each neuron executes its function for arriving signals. It maps input features to input membership functions. Mapping is done between the input membership functions and the if-then rules. These rules are further mapped to a set of output features. Finally, the output features are mapped to output membership functions which are further mapped to the decision which is associated with the output. ANFIS is an effective soft computing technique with easy implementation and easy incorporation of both numeric and linguistic knowledge for solving a problem. Fig. 3 shows the architecture of an ANFIS.

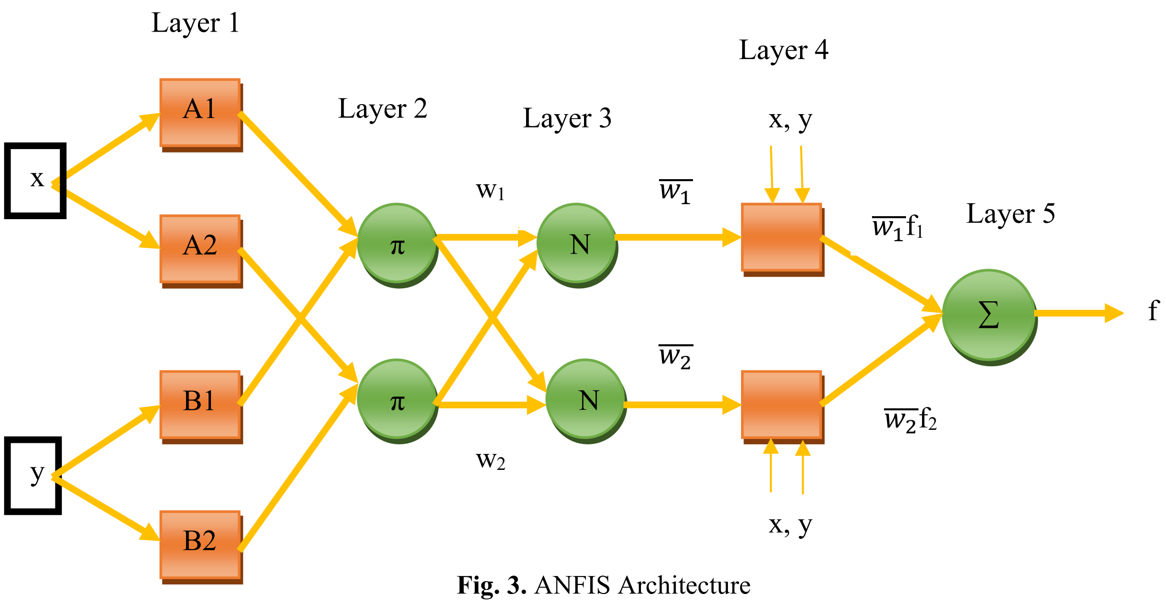


Fig. 3. ANFIS Architecture

Each layer in ANFIS contributes in calculating the parameters with the help of the respective functions present in them. The working of each layer is briefly described as follows:

1) *Layer 1:* Every node in layer 1 is an adaptive node. In this layer, the output of each node is fuzzy membership grade of the inputs. Here, the parameters are known as premise parameters. During the process of learning, different parameters are used for the specification and tuning of membership functions. The membership function can be represented in equation 5.

$$\mu_{Ai}(x) = \frac{1}{1+\left|\frac{x-c_i}{a_i}\right|^{2b}} \tag{5}$$

where, $\mu_{Ai}(x)$ lies between 0 and 1;

a_i, b, c_i are parameter set

2) *Layer 2:* Each node is a fixed node in this layer. Product of input signals is the output of the nodes in this layer which can be written as given in equation 6.

$$O_{2,i} = w = \mu_{Ai}(x) \;.\; \mu_{Bi}(x) \tag{6}$$

3) *Layer 3:* All nodes in this layer are fixed nodes. They calculate the ratio of the i^{th} rule's firing strength relative to the sum of all rule's firing strengths. The normalized firing strength is the output which can be written as given in equation 7.

$$O_{2,i} = \overline{w} \times w_1 \Big/ (w_1 + w_2) \tag{7}$$

4) *Layer 4:* Each node in layer 4 is an adaptive node. The output of these nodes can be defined as given in equation 8.

$$O_{4,i} = \overline{w_i} f_i = \overline{w_i}(p_i x + q_i y + r_i) \tag{8}$$

where, $\{p_i, q_i, r_i\}$ is the parameter referred to as consequent parameters

5) *Layer 5:* In this layer, all nodes are fixed nodes. Their job is to sum all arriving signals and output that as total output. The total output can be defined as given in equation 9.

$$O_{5,i} = \sum \overline{w_i}\, f_i \tag{9}$$

ANFIS identifies the rules on its own and tunes the membership function parameters accordingly. In order to develop an efficient model, some choices should be made carefully. For example, setting the optimization methods, types of output MFs and the number of epochs.

5. ANFIS Based Compatibility Model for IoT integrated Websites

Interacting with things via websites demands distinctive design considerations to eventually enhance the user experience. It is thus imperative to investigate the worthiness of a website for IoT integration. In this work, we propose an ANFIS model for evaluating the compatibility of website design and IoT device integration. Various e-commerce websites have been collected (with the domain .com) and 7 website design features have been identified which typify the compatibility of website with IoT devices. An ANFIS model has been trained with these 7 features and tested for the testing data. The ANFIS output as $IoTScore_{site}$ has been observed for the sample websites. Fig. 4 depicts the architecture of the proposed model.

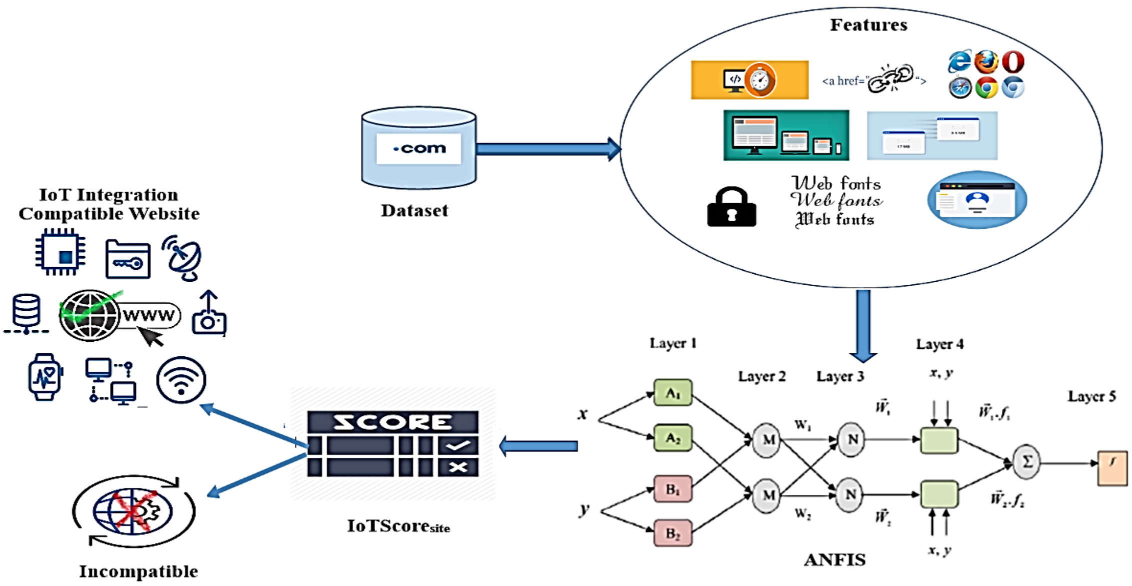


Fig. 4. Graphical illustration of the proposed model

5.1. Dataset Preparation

A top-level domain recognizes a certain element regarding the associated website type, such as its objective (business, government, and education), its owner, or the geographical area from which it belongs. Examples of some of the popular top-level-domains include .com, .org, .net, .gov, .biz and .edu. Since this work is to propose a model for the evaluation of business websites compatibility with IoT integrated devices we consider only the .com websites. In this work 600 e-commerce websites (with the *.com* domain) have been evaluated for compatibility with IoT devices using an adaptive neuro-fuzzy inference system. Also, we have identified 7 features of website design which impact the compatibility of website with IoT devices and are imperative to predict the IoTScore of a website. These features are as follows:

- Page Loading Speed
- Broken Links
- Browser Compatibility
- Resolution
- Total Size
- Privacy and Security
- Interface and Typography

The features have been derived from the design considerations for successful IoT interactions with website [14]. Fig.5 illustrates the mapping between the aforementioned website design considerations for IoT integrated websites and website design features used in this study.

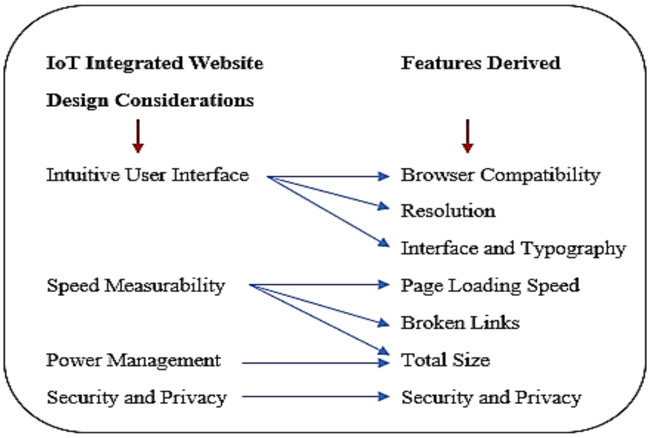


Fig.5. Derived features for IoT Integrated Website Design

The following subsections describe these features and their evaluation criteria.

5.1.1. Page Loading Speed

Page loading speed is defined as the 'speed by which a web page loads [31]. It is inversely proportional to page loading time which is, the time taken by a web page to load completely.

Evaluation Criteria: An online tool "GTMETRIX[2]" has been used to determine the loading speed. It gives the percentage value for a page's speed. In this study we have converted the percentage to score out of 10. For example: 81% - 90% has been scored as 9.

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[2] gtmetrix.com

5.1.2. Broken Links

Broken Links are 'links that don't work and send visitors to a webpage that no longer exists' [43]. It occurs due to variety of reasons such as:

- Non availability of webpage.
- Movement of webpage without a redirect being added.
- Change in the URL structure of website.

Evaluation Criteria: Another online tool "DEADLINKCHECKER[3]" has been used in this study which crawls through the website to identify presence of broken links. The evaluation criteria is based on the percentage of broken links found and the score have been assigned as given in table 1.

Table 1. Evaluation Criteria based on Percentage of Broken Links.

Percentage of broken links	Score
0	10
0 – 0.010	9
0.010 – 0.020	8
0.020 – 0.030	7
0.030 – 0.040	6
0.040 – 0.050	5
0.050 – 0.080	4
0.080 – 0.100	3
0.100 – 0.200	2
0.200 – 0.500	1
> 0.500	0

5.1.3. Browser Compatibility

Browser Compatibility is defined as the 'capability or flexibility of a website to function on different web browsers [31].

Evaluation Criteria: The websites have been browsed via various browsers namely: Google Chrome, Internet Explorer, Mozilla Firefox, and Microsoft Edge. Websites show varied behaviours with these browsers. Some websites are not compatible with all the browsers. Scores in the range of 1 to 10 have been given to websites assigning 2.5 for compatibility with each browser.

5.1.4. Resolution

Resolution is defined as 'the number of pixels present on a display screen where a pixel represents an individual point of color. The resolution is generally expressed in terms of the number of pixels on the horizontal axis and the number on the vertical axis'. The resolution feature is used to evaluate the appearance of website with different screen sizes.

Evaluation Criteria: The website either showed same or varied behaviour with different screen sizes. Scores in the range of 1 to 10 have been given in accordance to the ability of websites to adapt with different screen sizes, where a value of '1' corresponds to the websites which are unable to adjust effectively to different screen sizes and a value of 10 indicates the website is able to adapt itself to various screen sizes. Websites which are able to adjust with different screen sizes have been given

[3] www.deadlinkchecker.com/

higher scores and websites which show distorted content when evaluated on small screen sizes have been given lower scores.

5.1.5. Total Size

Web page size is an integral feature which determines the speed of page loading as the bigger a page is, the longer it takes to load the required resources to display it. Total Size is the size of web page in MB. *Evaluation Criteria:* For evaluating the size of webpage, an online tool *"GTMETRIX"* has been used in this study. Table 2 gives the scoring criteria of websites based on its total size.

Table 2. Scoring criteria based on total size of a website.

Web page size (in MB)	Score
> 50 MB	0
25 – 50 MB	1
15 – 25 MB	2
13 – 15 MB	3
11 – 13 MB	4
9 – 11 MB	5
7 – 9 MB	6
5 – 7 MB	7
3 – 5 MB	8
1MB-3MB	9
< 1 MB (in KB)	10

5.1.6. Privacy and Security

Privacy and Security determine the steps taken while website design to secure the information and prevent websites from hackers and malwares.

Evaluation Criteria: For assessment of website privacy and security, an online tool "*Qualys SSL Labs*[4]" has been used. It grades the website as A+, A, B+, B, C and D based on Cipher Suits and Strength, SSL/TLS version, Key Exchange, Handshake simulation, Protocol Support and Details, BEAST and much more. A score of 10 has been given to the websites evaluated with A+ grade, 8 to A grade websites, 6 to websites with B+ grade, 4 and 2 to C and D grade websites respectively.

5.1.7. Interface and Typography

Intuitive Interface is defined as the extent of ease by which a website can be used and understood. Typography & Font is based on font size, font style and readability of website's content [31].

Evaluation Criteria: In this work interface of a website is evaluated using crowded sourcing and websites are scored in the range of 1 to 10 depending on its ease of usage. Also, typography and font has been evaluated and weighted average of interface score and font score has been used to determine overall score of this feature. Highest score has been given to 12-point Arial font because of its legibility and sharpness. It is also considered as the most preferred font by websites users [44]. Lower to it is scored 12-point Times New Roman as it is considered as the fastest to read font by users [44]. The other fonts lagging behind in the queue are 12-point anti-aliased Arial, 10-point Arial, 12-point anti-aliased Times New Roman, 10-point times New Roman which have been scored with decreasing values. Other fonts sizes and styles have been scored as per their readability.

[4] www.ssllabs.com

Intuitive interface and typography score has been calculated using the equation 10:

$$\frac{\alpha.IS + \beta.TFS}{100} \tag{10}$$

where,
IS is the Interface Score attained by crowd sourcing,
TFS is the Typography and Font Score,
α and β are the coefficients where $\alpha = 100$ and $\beta = 10$.

The websites in the dataset are labelled with the $IoTScore_{site}$ based on the sum of all the feature scores. This cumulative score, $IoTScore_{Site}$ finally characterizes the compatibility score of the website to IoT devices. The generated scorecard depicts the integration support that these websites have. The compatibility thresholds for integration support are as given in table 3.

Table 3. $IoTScore_{Site}$ Evaluation

Sum of Features Score	$IoTScore_{site}$	Compatibility
>=50	2	Website design is *highly compatible* with IoT devices
>=30	1	Website design has *medium compatibility* with IoT devices
<30	0	Website design is *not compatible* with IoT devices

5.2. ANFIS Implementation

The ANFIS implementation contains two processes: that is , the ANFIS system training and the model testing. The following sub-sections describe the details.

5.2.1. ANFIS System Training

A typical ANFIS training process has been depicted in Fig. 6 [45]. The first step is to obtain training and checking data sets. Training data set must have an output vector which contains the output for every set of inputs. The premise parameters for MFs are set by using training data set. A threshold error value is determined. Least squares method is used to find consequent parameters. The premise parameters are updated using the gradient decent method if error is greater than threshold. Once the error comes out to be lesser than the threshold value, the process terminates. The role of checking data set is to compare the predicted values to actual values [45]. Hybrid learning is used by ANFIS for learning while training. Hybrid learning is an integration of the gradient descent and the least squares method. The first step of ANFIS training in MATLAB is to create training data set. The data set must be in the form of a matrix where the output should be in the last column. The number of columns depend on the numner of inputs and the rows denote the existing data points. There are 2 commands in the matlab to generate FIS using the training data set namely GENFIS1 and GENFIS2. However, these two commands differ in a way that GENFIS1 produces grid partitioning of the input space to generate the FIS and thus it is more likely to have the problem of the ``curse of dimensionality", while GENFIS2 uses subtractive clustering (SUBCLUST) to produce scattering partition. Due to this reason in this study, we have used the GENFIS2 command for generating the FIS. After setting the number of epochs matlab system training begins.

Once the training process terminates, we get the final membership functions and training. ANFIS functions well with one training data set but, if checking data set is also provided then the chances are more that system will understand the model more accurately. Using evalfis function, system performance can be evaluated.That is, the trained model is tested for different sets of inputs in order check its performance.Here, we used the dataset created in the previous section.

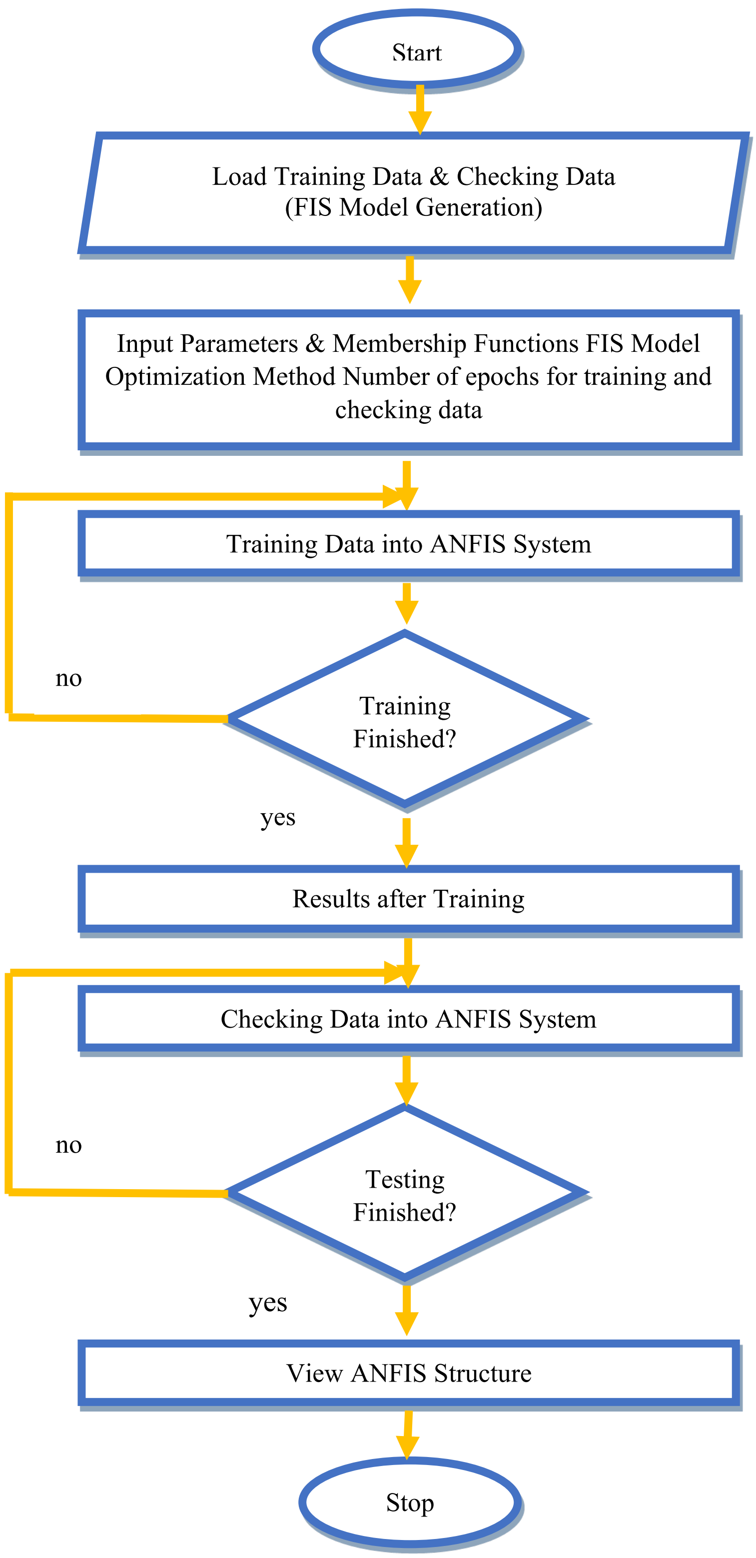

Fig. 6. ANFIS Training Process

5.2.2. ANFIS Model Testing

ANFIS model testing is done to validate the model which is a process by which the input vectors on which the FIS model was not trained are given to the trained FIS. It is done to check the ability of the FIS model to predict the output values corresponding to the given input vectors and to check its generalization capability [46]. Validation of the model is done after the FIS is trained using a testing data which is different from the data set used for training of FIS.

6. Results and Discussion

In this research ANFIS model is implemented to evaluate the IoT compatibility of website designs. Section 6.1 describes the ANFIS model training process. Section 6.2 describes the result of model testing. Section 6.3 gives the ANFIS output for a sample website based on the rules generated.

6.1. Training ANFIS

The parameters selected to generate the FIS are given in table 4.

Table 4. Parameter Setting

Parameter	Value
Range of Influence	0.5
Accept Ratio	0.5
Reject Ratio	0.15
Squash Factor	1.25

The ANFIS model has 7 inputs and 1 output. In this study we choose the sub-clustering method to generate the FIS. The sub-clustering method generates a FIS with following details as given in table 5.

Table 5. Generated FIS

No. of inputs	7
No. of outputs	1
No. of MFs	38 38 38 38 38 38 38

The fig. 7 illustrates the FIS generated with 7 inputs represented as initial black discs, 38 clusters for each input represented as white discs, 38 rules as blue discs, 38 output MFs as the next white discs, one aggregated output and one final output.

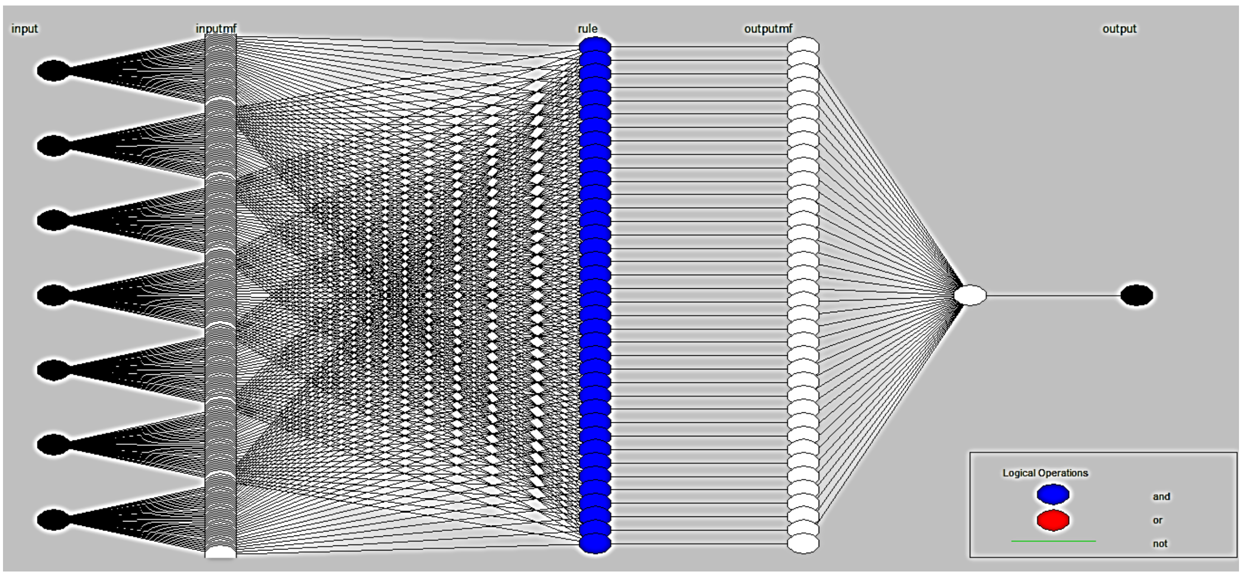

Fig. 7. Structure of Generated FIS

The Epoch 1 error was observed to be 0.2048. We trained the FIS with epoch 100 and epoch 150. It was observed that the training error was decreased as the number of epochs increased but the checking error increased. Table 6 represents the training and checking error with epoch 100 and epoch 150.

Table 6. Training and Checking Error with Varying Epochs

Epoch	Training Error	Checking Error
100	0.1467	0.6001
150	0.1414	0.6731

The fig. 8 shows the trends of training and checking error with respect to number of epochs.

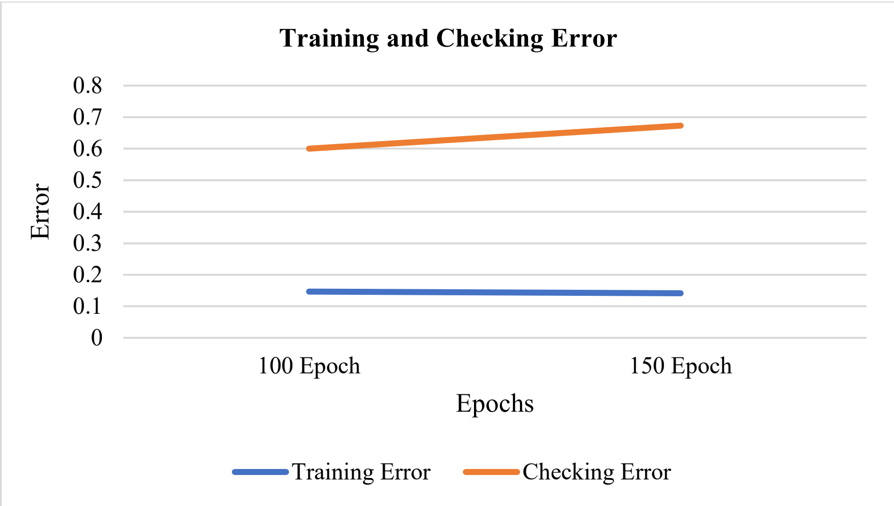

Fig. 8. Training and Checking Error w.r.t Epochs

As the checking error increases with no. of epochs we chose 100 epochs for training the FIS and build the final model. The fig. 9 represents the graph for training data with which the FIS was trained and the fig. 10 represents graph for checking data.

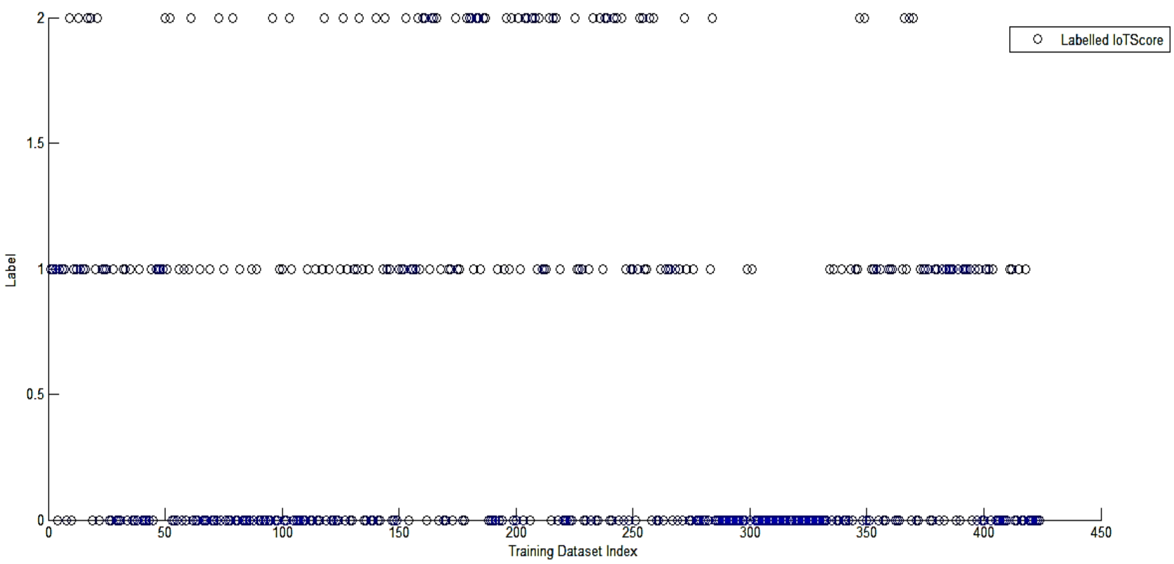

Fig. 9. Training Data Distribution

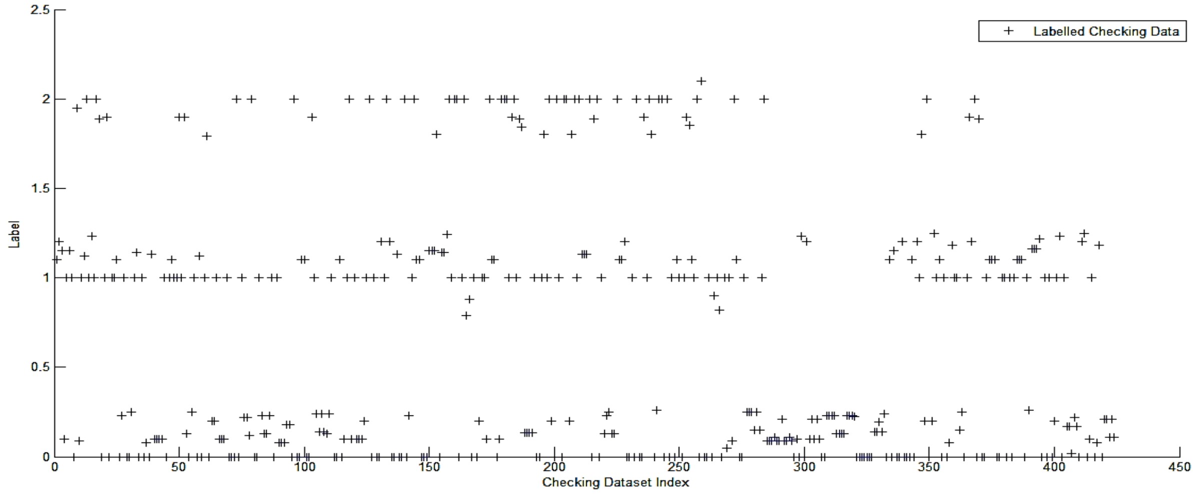

Fig. 10. Checking Data Distribution

The total number of parameters and fuzzy rules for ANFIS were 836 and 38 respectively, as shown in table 7.

Table 7. ANFIS Information

ANFIS Item	Value
Number of nodes	618
Number of non-linear parameters	532
Number of linear parameters	304
Number of total parameters	836
Number of training data pairs	424
Number of checking data pairs	424
Number of fuzzy rules	38

The error tolerance was set to zero and model optimization was chosen to be *hybrid*. The hybrid optimization method is a combination of least squares and back propagation gradient descent method [47]. After training of ANFIS, the training data errors and checking errors were plotted against the number of epochs as shown in fig. 11.

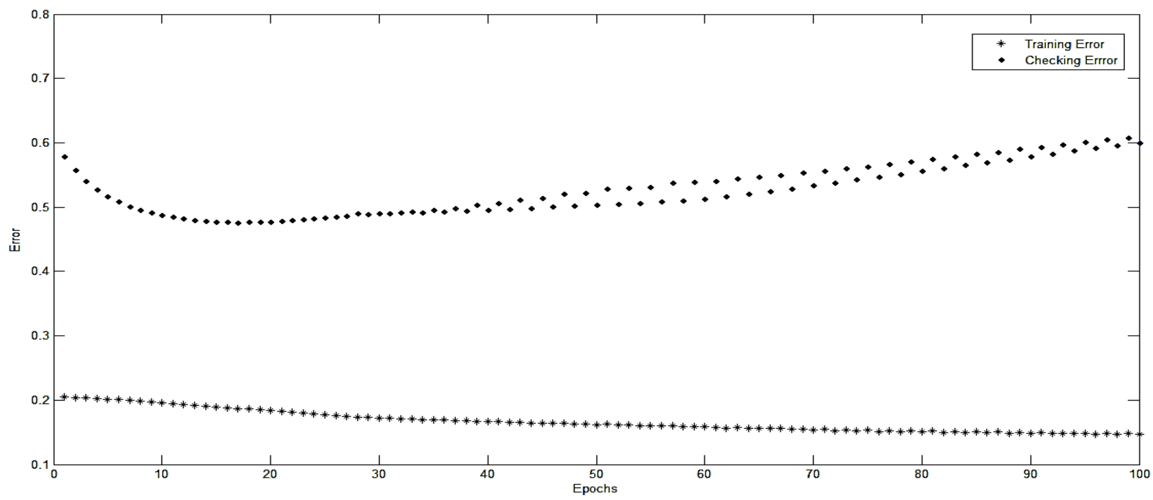

Fig.11. Training and Checking Error

The checking error rises up after a certain point till where it decreases which is the point of model overfitting. ANFIS automatically selects its parameters allied with the minimum checking error (just prior to this jump point).

At epoch 100 the training error and the checking error were observed to be 0.1467 and 0.6001 respectively. The fig. 12 represents the fall of training error as the number of epochs increases.

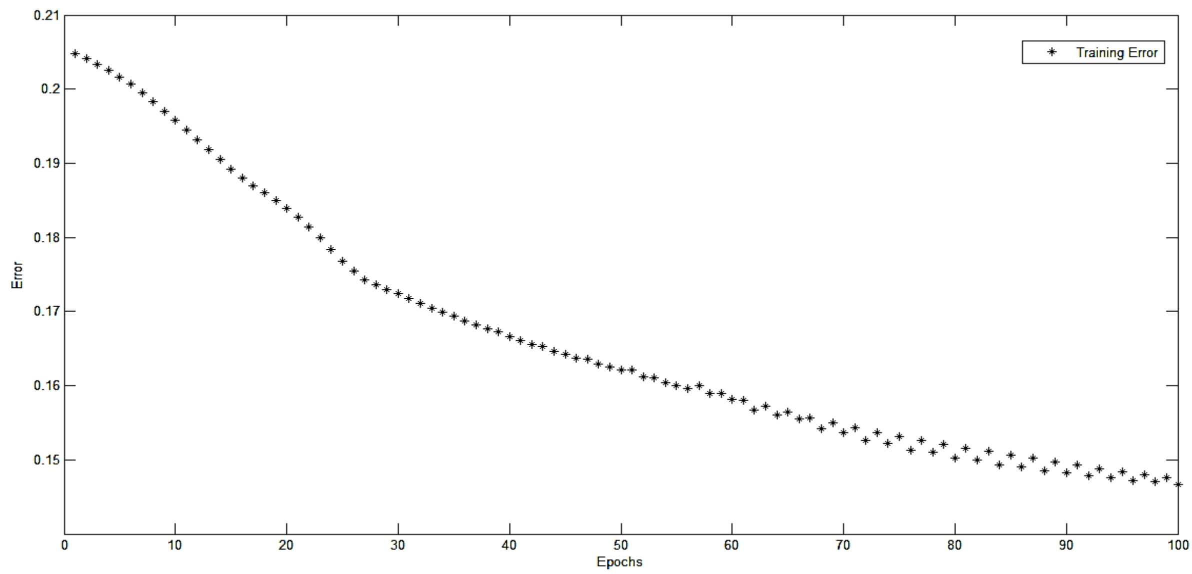

Fig. 12. Training Error w.r.t Epochs

The fig. 13 shows the result of testing the checking data against the trained FIS. The average testing error in this case came out to be 0.6001.

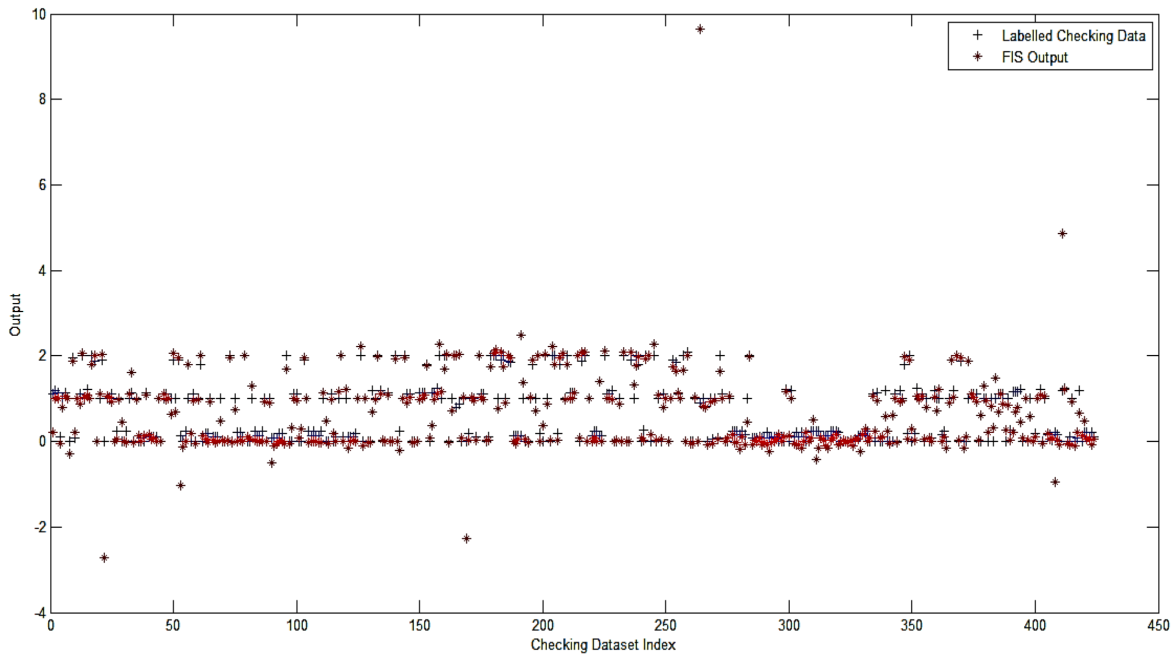

Fig. 13. Testing Checking Data against the Trained FIS

6.2. Testing the model

The fig. 14 represents testing data points graphically. The number of test data pairs are observed to be 201.

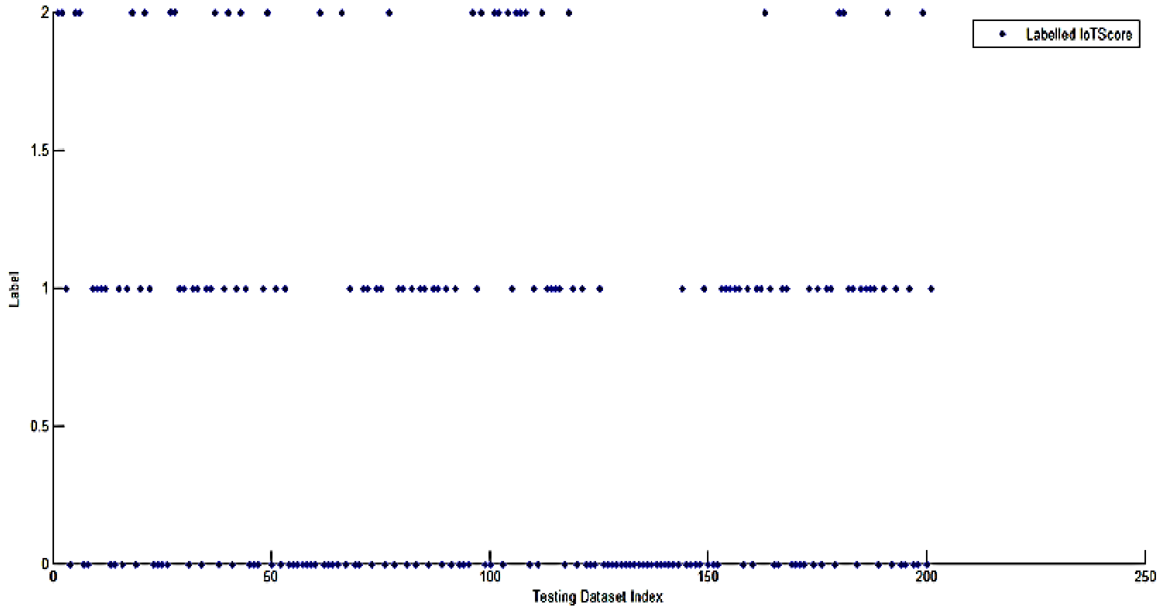

Fig. 14. Test Data Distribution

Fig. 15 shows the result of testing the model against training data itself. The average testing error in this case came out to be 0.1467.

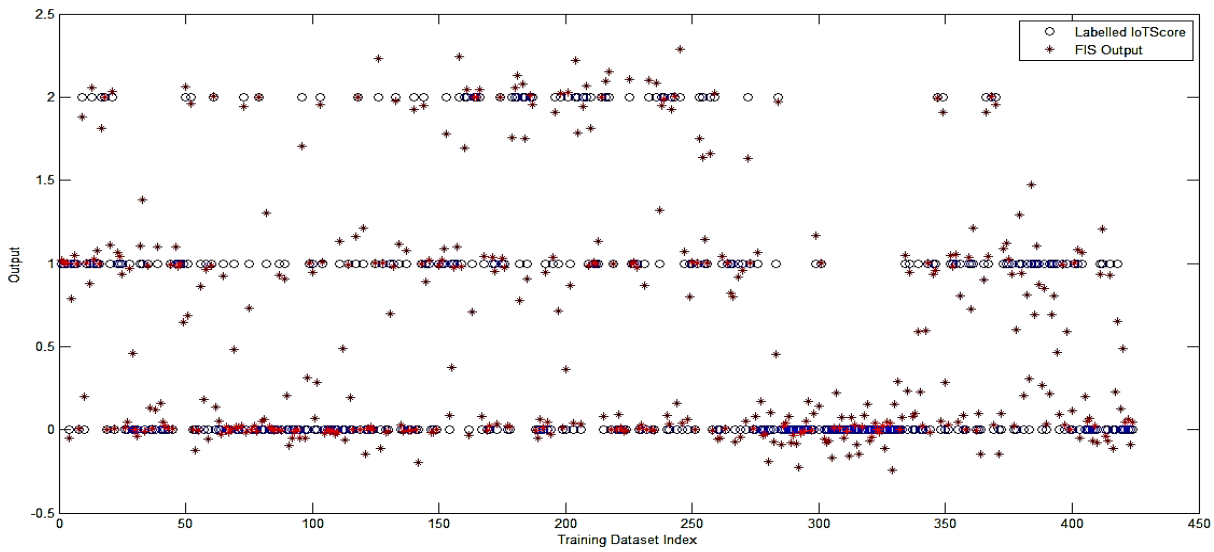

Fig. 15. Training Data Points and FIS Output

The performance of the proposed model is shown in fig. 16 which shows the plot of actual and predicted values of website quality for testing data. The average testing error came out to be 5.0941.

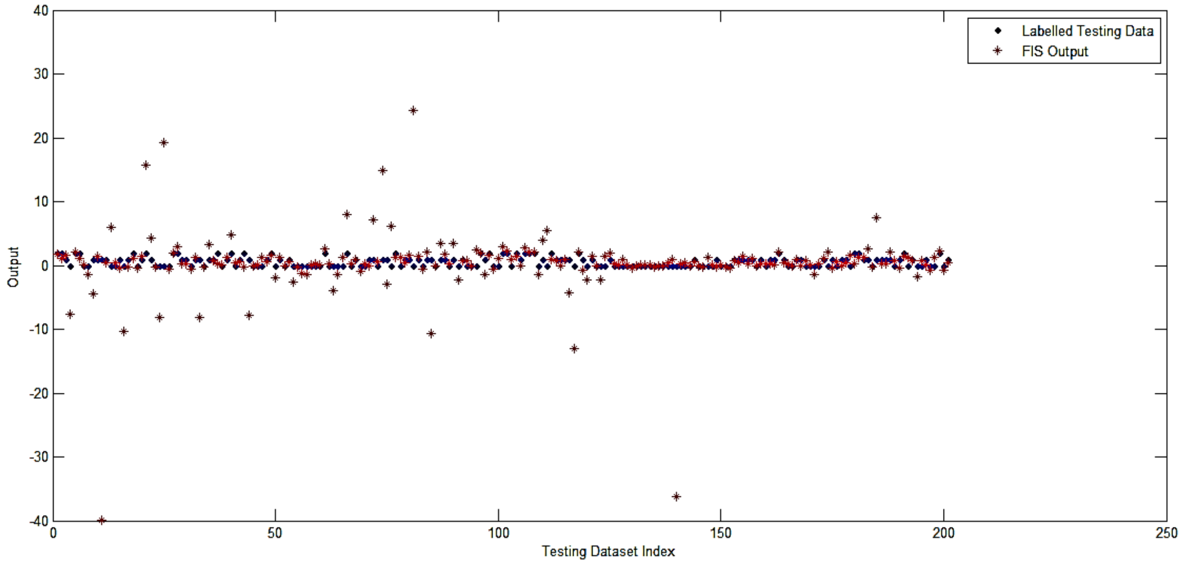

Fig. 16. Testing Data Points and FIS Output

The table 8 represents the summary of training and testing ANFIS model for evaluating $IotScore_{site}$ for the training and testing data.

Table 8. Summary of ANFIS Model

Epoch	Training Error	Average Testing Error
100	0.1467	5.0941

6.3. ANFIS Output

The example of IoT compatibility has been illustrated below for a sample website. Inputs for the sample website are given in the table 9.

Table 9. Feature Input Values

Input No.	Input Value
Input 1	6
Input 2	5
Input 3	7
Input 4	9
Input 5	5
Input 6	5
Input 7	9.5

The fig. 17 illustrate the rule base and evaluation of IoT scorecard for the sample website with the above input values.

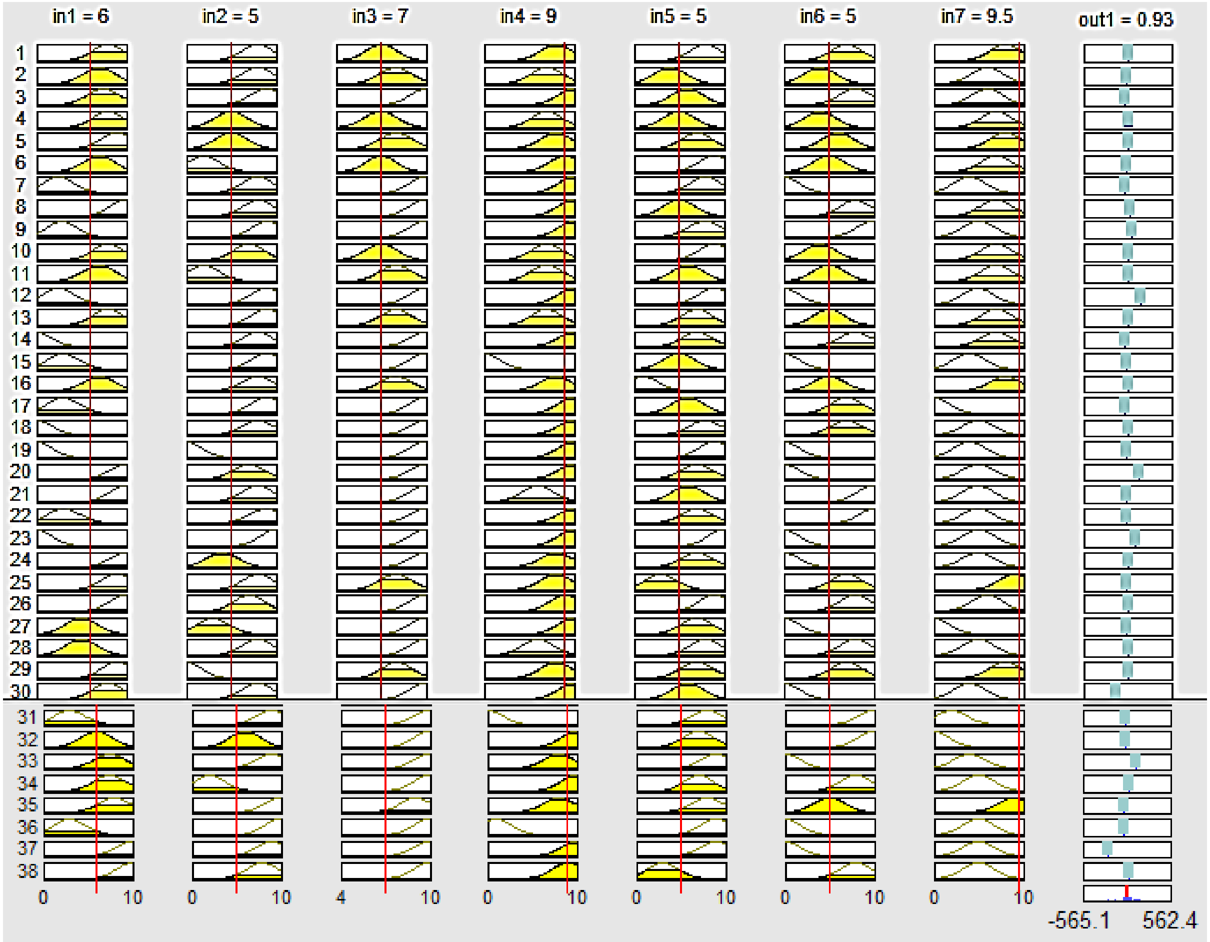

Fig. 17. Rule Base and Evaluation of $IoTScore_{site}$ for Sample Website

The output $IoTScore_{site}$ for the sample website is 0.93. The value of $IoTScore_{site}$ lies between 0 and 1 and closer to 1 which implies that the website has medium compatibility when integrated with IoT devices.

On evaluating all 600 websites, it was observed that more than 60% websites show low compatibility with IoT integrated devices with the value of $IoTSite_{score}$ closer to 0. Only 10% websites show a value closer to 2 and can be considered as IoT compatible websites. This creates an alarming situation for e-commerce websites and indicates that current business websites require major design changes and need to adopt new development strategies.

7. Conclusion

It is evident that at the heart of IoT systems are the User Interface (UI) which comprises the visual elements of a page and the User Experience (UX) which focuses on site navigation, search engine optimization, and research and analytics. Web designers are the architects of these elements and are responsible to build sites that communicate with back-end databases that have collected information from IoT devices and create front-end interfaces, allowing users to interact with numerous devices that frequently have different screen sizes or run on different platforms. This study evaluates the websites integration capabilities and support to IoT devices and depicts that most of the samples in the show low or medium IoT integration compatibility instigating new challenges for web developers in terms of both back and front end design to make a website worth for IoT integration. The proposed ANFIS generates a compatibilty score $IoTScore_{Site}$ to comprehend the interconnected development, new devices and web development methodologies which create new business opportunities.

IoT is *not* the end product and customers do not buy IoT. It is not simply an iPhone, a networking application, or a wearable device. It requires a technology-aware approach to product experience which includes upgrades, adapting to other products, personalization, and big data [48-52]. As a future direction, ensemble machine learning methods [53], deep learning models such as recurrent neural networks and convolution neural networks can be implemented to evaluate the compatibility of website design with IoT integrated devices. Also, compatibility studies with respect to integrating IoT to applications, cloud service, big data and semantic web technologies need investigation.

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