Software Engineering
2018; 6(3): 98-109
http://www.sciencepublishinggroup.com/j/se
doi: 10.11648/j.se.20180603.13
ISSN: 2376-8029 (Print); ISSN: 2376-8037 (Online)

A Fuzzy Prototype Solution for Website Quality Assurance

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To cite this article:
Akinola Olayinka, Odunayo Adesola Aribisala, Nwankwo Wilson, John Temitope Ogbiti. A Fuzzy Prototype Solution for Website Quality Assurance. *Software Engineering*. Vol. 6, No. 3, 2018, pp. 98-109. doi: 10.11648/j.se.20180603.13

Received: July 4, 2018; **Accepted**: July 19, 2018; **Published**: September 26, 2018

Abstract: Internet has become ubiquitous and organizations have moved from the traditional storage using physical files localized in cabinets to online remote storage accessible over websites. Over the years, different website evaluation tools have been developed to assist web administrators with website maintenance functions. Prior to a proper website assessment using majority of such tools, the web administrator would have to access each one differently reasons being that each tool is developed to measure different quality parameters. Later, Fuzz-web was developed to capture more parameters but with a limitation wherein the system depends on some of the evaluation tools for inputs, the implication being that where such tools are not available there will be an express failure of fuzz-web. To overcome the foregoing problems, this paper is aimed at developing a Fuzzy-Based Website Quality Assurance System. It employs fuzzy logic principles, exploiting the inherent power of the Java programming language to evolve a system that can be used to detect broken links, slow loading pages, Hypertext Transfer Protocol-related errors in a website, and the overall quality status of a website. The system relieves the user of the gross dependence on several external evaluation tools and with the information provided, enhances the proactive web administrators to be proactive in amending errors.

Keywords: Fuzzy System, Fuzzy Logic, Web Evaluation, Quality Assurance, Web Maintenance

1. Introduction

Information is defined as the knowledge acquired or supplied about something or somebody; the collected facts and data about a specific subject; the communication of facts and knowledge (Encarta dictionaries, 2009). It is often said that information is power. The importance of information to individuals and organizations and the need to adopt quality information management techniques cannot be over-emphasized. The critical role information plays in the daily life especially in driving communication, decision making, reactions around the entire environment, to mention a few, has continued to be the driving force behind the development of new information management technologies and tools. One of the prominent technologies in this context is online cloud storage whereby individuals and organizations store vital information related to products, services, transactions, documents, etc. away from the originating site to a remote online server elsewhere over the Internet. The reasons for the foregoing is often connected to security, safety, and ease of access outside the organization.

According to Brahima [1] statistics on information technology show that by the end of 2014, there would be almost 3 billion Internet users, two-thirds emanating from the developing countries, and the number of mobile-broadband subscriptions growing towards 2.3 billion globally. Fifty-five per cent of these subscriptions are also expected to be in the developing countries. According to Kende [2], the proportion of Internet user worldwide rose at a compound annual growth rate of 12% from 2008 to 2012, and reached 37.9% of the global population in 2013. He noted that increase in usage is clearly and more distributed across those regions that had recorded lower Internet usage in 2008. The growth rates in sub-Saharan Africa and Asia-Pacific exceeded 20% within the period in question. With the foregoing results, it is obvious that the number of Internet users across the globe increases by the day.

People are more informed than ever these days. People put in a lot of time and effort to conduct detailed research before making an online purchase. In fact, 63% of people use the Internet as their first resource when looking for a local service or product, according to a study by Nielsen [3]. According to Small Business Watch Survey in 2012, 3,000 people were surveyed and 47% of them responded that they are more likely to purchase services or products from a small business with a website. This indicates that people are more willing to trust businesses that have a website. Moreover, putting a business online increases its chances of being listed in search sites, like Google, Yahoo and Bing. This will help people locate the said business easily**.** Considering the testimony of Michelle Braun, owner of Final Touch Housekeeping in Aurora, Colorado, in [4], she recorded an increase in business after creating a website. Braun initially used flyers and other printed materials to promote her business, but customers kept asking for her web address and she quickly got a website up and running in July 2009.

She witnessed an increase in the number of deals she closed, within a year she was able to do bids for 500 or 600 people, all contacted through her website.

According to Ghandour [5], "a website is a sales channel between the business, customers and the world at large". In the contemporary competitive business environment, an innovative, well-designed and managed website can provide the advantage a business needs to conduct its activities successfully. Having a website attracts some business benefits; it is a great way to increase business sales and leads. Websites broaden the market reach for business and provide customers 24/7 access to products and/or services. For small-to-medium sized businesses, a website can level the playing field when competing with larger companies. Having a website indicates one's commitment to prospective customers as well as a competitive edge over other entities in the same or similar line of business. A website also enhances connections with people having regard to the fact that a major important factor in business development is networking. Through a website unlimited number of contacts on a 24/7 basis could be attained at a limited cost.

1.1. Structure of the Web

World Wide Web (WWW) introduced the principle of universal readership, which stated that networked information should be accessible from any type of computer in any country with one easy to use program [6]. With the principle stated above, if information is available, then any (authorized) person should be able to access it from anywhere in the world. The client-server model was used in the implementation of the web, where a user relies on a program (the client) to connect to a remote machine (the server), where the data is stored. The architecture of the Web is represented in figure 1

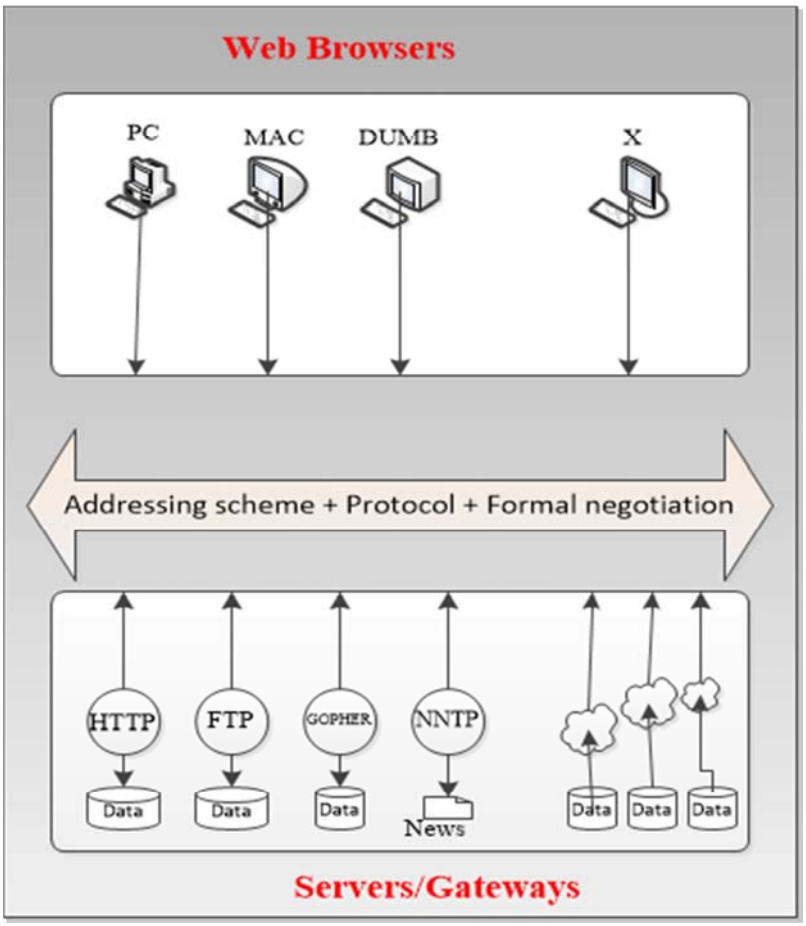

Figure 1. *Architecture of the Web (Berners-Lee et al., 1992).*

A major characteristic of a typical Web document is its hypertext structure (see Figure 2). In traditional web pages or documents, a given reference could be represented using an underlined text or an icon. The user may elect to click on it with his mouse to navigate to the referenced document appears [7] provided he is connected to the Internet or Intranet as the case may be. With the hypertext feature, copying of information across pages becomes unnecessary that is, data needs to be stored once, and all references to it can be linked to the original document.

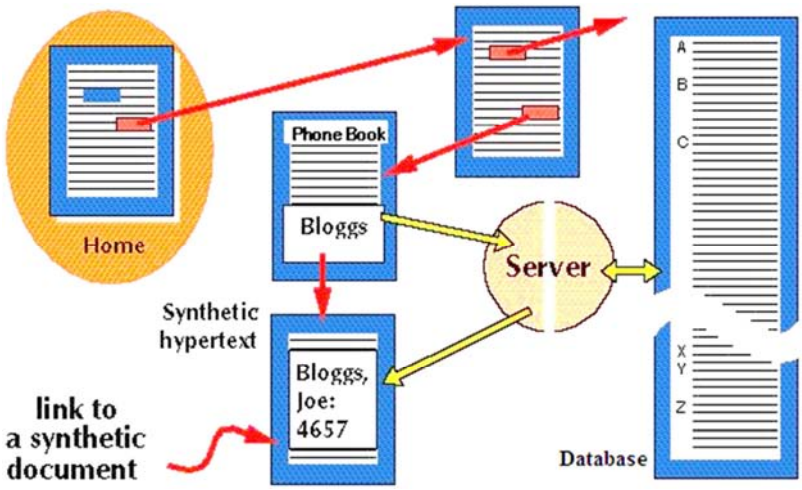

Figure 2. *The basic Hypertext Model (Berners-Lee et al., 1992).*

1.2. Statement of the Problem

As an organization, it is not sufficient to have a website; the quality aspect of a website should always be carefully considered. Though quality is a relative term, when applied to web pages there are parameters to watch out for. For instance, the loading speed of web pages should not be tolerable to an average user i.e. web pages should be designed bearing in mind the usability and server/web browser loading factors respectively; web page errors should be avoided or reduced as much as possible, just to mention a few. Studies have shown that users who do keyword searches spend an average of 12 seconds on any of the returned web pages [8]. This implies that every online business has a limited time to convince or retain a potential customer on its website**.** Consider the following scenario:

a. A potential buyer of a company's product tries to browse through the company's online catalogue, but the product's gallery section of the website has an error, so the potential buyer simply moves on to the company's competitor website, browses their catalogue and makes his purchase.
b. A potential customer needs a particular service or needs to make a purchase, decides to browse through company's sites offering the desired service / product, only to find out that a particular site is not opening on time while other competitors' sites have opened and he has checked what he needs, he definitely would have lost interest in the site that is not opening even if they have the best offer compared to their competitors.

In the foregoing scenarios, the actual underlying problem had to with the maintenance of those websites. Most effort in this regard has always been manual, such that a resource or team, usually from the Information Technology (IT) department of an organization is saddled with the responsibility of ensuring the website is well maintained. The above function can become overwhelming especially when web pages and/or content increase. When this happens, it becomes a tedious task for the team or person in charge to contain the maintenance requirements across all the pages of the website. The IT staff may not be aware of the error (s) till it becomes an issue, which may have resulted in loss of customers or customer confidence in the company or loss of revenue altogether. Over the years, some developers introduced different tools that can be used by web administrators to maintain websites. But the limitation with majority of the tools is that each tool addresses a particular problem, for example, a tool might be used to identify broken links on websites while another might be for identifying the speed of webpage load etc. That is, for a web administrator to identify more than one problem on a particular website, he must, as a matter of necessity, have access to the different tools. Regrettably, the unavailability of a given evaluation/maintenance tool would imply a stall of the maintenance process or at best a shallow and inconclusive maintenance operation.

1.3. Motivation for the Study

Fuzzy logic is a technique that enables solving difficult problems with many inputs and output variables. It usually offers results in the form of recommendation for a specific interval of output state. The foregoing accounts for its wide application in the field of Artificial intelligence especially in various fuzzy control systems. This powerful technique may be adopted in developing self-sufficient system that can assist web administrators in evaluating their websites for quality status rating over time.

1.4. Aim and Objectives of the Study

The aim of this study is to develop a simplified but comprehensive automated fuzzy system that could be embedded in a given website or used as a standalone website quality assurance tool that integrates various parameters that constitute the quality components of a website. The objectives of this paper are to:

a. Formulate fuzzy rules to guide the decision making of the system
b. Design and implement a comprehensive fuzzy-based website quality assurance system

1.5. Related Work

1.5.1. Information Retrieval and the Web

Until the early 1980s information retrieval was considered as a narrow area of interest by librarians and information experts. Many people have envisaged a universal information database since late 1940s whereby data collections could be stored and made accessible to users across the world with links to other collections of data stored in other places, and in such a way that only the most important data would be quickly found by a user [9]. The World Wide Web was introduced in 1990 by the European Laboratory for Particle Physics, as physicists' innovative ways of sharing information [10]. The concept involved the ability of people working in different locations to learn what each other were working on, through examination of a hypertextual document, accessible on the Internet. Creation of the World Wide Web is often credited to Tim Berners-Lee [11]. Lee's initial perspective of the web was "a simple scheme to incorporate several different servers of machine-stored information already available at CERN". This "scheme" was to use hypertext to provide a single user-interface to many large classes of stored information such as reports, notes, data-bases, computer documentation and on-line systems help [12] The official description defines the Web as a "wide-area hypermedia information retrieval initiative aiming to give universal access to a large universe of documents" [9]. It can simply be said to be an Internet-based computer network that allows users on one computer to access information stored on another through a series of interconnected networks. The content of information present in the web is diverse not only with respect to quality but also in language, range of vocabulary and type [13].

1.5.2. Broken Links

Links are the programmatic commands to 'jump-to-another-page' in a web browser. Every webpage is filled with dozens of links, each sending a user to some related web page or picture/file. A link is identified if the mouse pointer changes to a pointing finger when the mouse is placed on its text. Clicking a link or hyperlink is all it takes to activate the jump command from a page to another segment in the same page or to another page. When a web user clicks over a link, the hyperlink instructs the web browser to load the target web page or segment, ideally within seconds depending on the speed of the Internet connection. Indeed, hyperlinks are the very core of how the World Wide Web functions. Millions of hyperlinks are how people jump and discover the massive content of the Web.

A link may be considered broken if the link or hyperlink does not direct the web browser to the supposed destination. A Broken link also called a dead link is a link on a web page that no longer works due to one or more of the reasons below.

a. An incorrect Uniform Resource Locator (URL) is coded against a link by the website designer or programmer.
b. Unavailability of the destination website or web page due to relocation to another server or permanent deletion
c. The user is under the control of a software or behind a firewall that blocks access to the destination website or web page.
d. The website is linked to a website located behind a firewall and which does not allow external access.

Generally broken links pose problems to users of a website and could be frustrating atimes as users are unable to access the desired resources. In some cases, the user may decide to leave the site for another site providing similar services. It may also make a company lose valuable customers owing to poor service quality and customer satisfaction. A site that hasn't been updated or checked for a long time may suffer from link rot, which is a term used to describe a site with dozens of broken links.

1.5.3. Website Maintenance

To manage a website especially a large website is practically difficult without an automated tool. Over the years, website evaluation tools have been developed to assist in maintaining a website with each tool focusing on one parameter that contributes to the quality website. For a web administrator to maintain a website, two or more tools are often deployed. Some of these tools are discussed in the following sections.

1.5.4. Xenu's Link Sleuth

This is a computer program that checks websites for broken hyperlinks. Developed by Tilman Hausherr, the Xenu's Link Sleuth is proprietary software though available at no cost. The software runs on Microsoft Windows. It is named after Xenu, the Galactic Ruler from Scientology scripture. With this program, a user can follow links to other pages, and checks the links on those pages in which case it is possible to check an entire website for broken links in one session. It can also display continuously updated list of URLs which may be sorted using different criteria. The program utilizes a "simple, no-frills user-interface", and can help users understand how certain Web sites are structured [14].

Limitation of Xenu, or Xenu's Link Sleuth

The software only checks websites for broken links; it does not give considerations to other parameters like the speed for webpage upload etc.

Webpage Speed Analyzers

There are different tools that have been developed to measure the speed of webpages. Some of these tools are: GTmetrix, Dotcom-monitor etc. majority of these tools exhibit obvious limitations. For instance, the focus of these tools is majorly on measuring and analyzing webpage load speed and not on the parameters that contribute to website's good quality.

1.5.5. Introduction to Fuzzy Logic

Fuzzy logic is a complex mathematical method that allows solving difficult simulated problems with many inputs and output variables [15-17]. It is able to give results in the form of recommendation for a specific interval of output state, so it strictly distinguished from the more familiar logics such as Boolean algebra [14]. The concept of fuzzy sets was firstly introduced by Zadeh in 1965. The author's intention was to create a mathematical representation for handling data imprecision and information possessing non-statistical uncertainties. Basically, fuzzy sets are a supplement of ordinary crisp sets. To differentiate between the two paradigms and capabilities of fuzzy sets, it is imperative to take a look at the definition of crisp sets [16] [18] and compare them to fuzzy set definitions.

2. Methodology and Design

2.1. Fuzzy-Based Website Quality Assurance System

The Fuzzy-based website quality Assurance System (FWQAS) takes into consideration the importance of treating all evaluation criteria in a modular fashion that is, all the quality parameters to be evaluated are bundled together in a single suite. Also, the need for dependence on external evaluation tools before the quality assessment system can perform its major task, which is one of the limitations of Fuzz-web, would have be dealt with, making the system to be self-sufficient to perform its overall task even in the case of failure or unavailability of any of the online evaluation tools. For the purpose of this work, three parameters will be considered and infused into the system, they are: broken links, errors and webpage load speed. The overall output the system will produce is the quality of the website.

2.2. Defining the Inputs/Output Membership Function for FWQAS

In this section we defined the fuzzy input parameters with their linguistic categories to be used. The input variables for the FWQAS are Broken links, Errors and Webpage Speed load. Two linguistic terms {unsatisfactory, satisfactory} are used to represent the input fuzzy sets while three linguistic terms represent the output {poor, fair, high}. The fuzzy input parameters were fuzzified using trapezoidal membership functions. Figure 3 shows the membership function distribution for the parameters:

Broken Link: The scale for broken links indicator is between 0 and 1, see equation 1. If the result tends to 1 then it reveals an acceptable score. The computation is given as:

$$\text{Broken Link (B)} = \frac{\text{Total number of un} - \text{broken links}}{\text{Total number of un} - \text{broken} + \text{broken links}}$$

Figure 3 illustrates membership functions of the broken link input parameter

$$\mu_{uns}(x) = \begin{bmatrix} 1, 0 \le x \le 0.3 \\ \frac{(0.7-x)}{0.4}, 0.3 \le x \le 0.7 \\ 0, \mathrm{x} > 0.7 \end{bmatrix}, \mathrm{u}_s(x) = \begin{bmatrix} 0, x < 0.3 \\ \frac{(x-0.3)}{0.4}, 0.3 \le x \le 0.7 \\ 1, 0.7 \le \mathrm{x} < 1 \end{bmatrix} \quad (1)$$

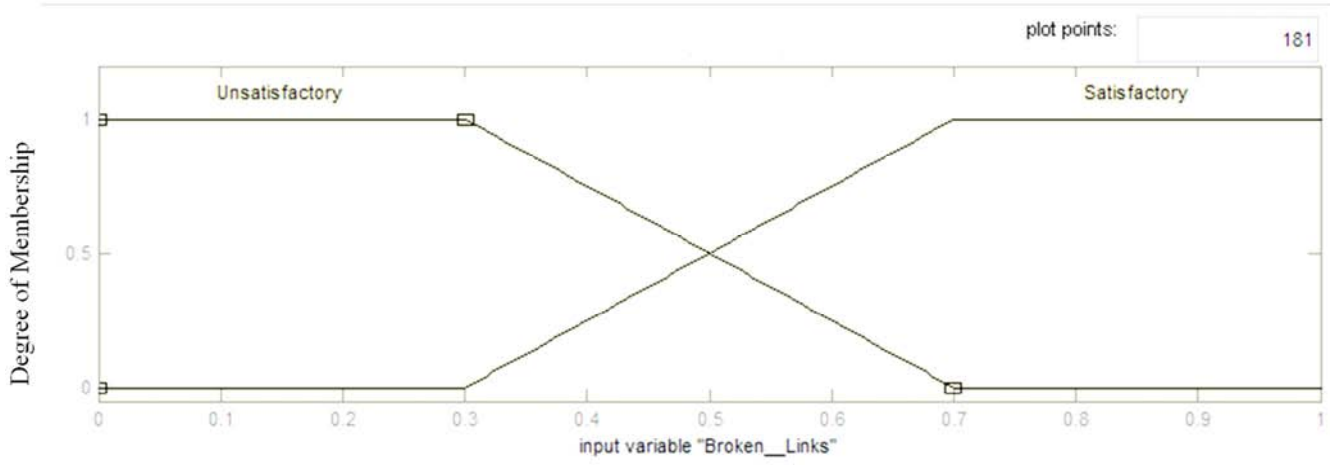

Figure 3. *Membership function of the input variable "Broken links".*

Errors: The scale for "Errors" indicator is between 0 and 1- see Equation 2. If the result tends to 1 then it reveals an acceptable score. Its computation is given as:

Errors (E) Total number of Error-free links / (Total number of Error links + Error-free links)
Figure 4 illustrates membership functions of the "Errors" input parameter

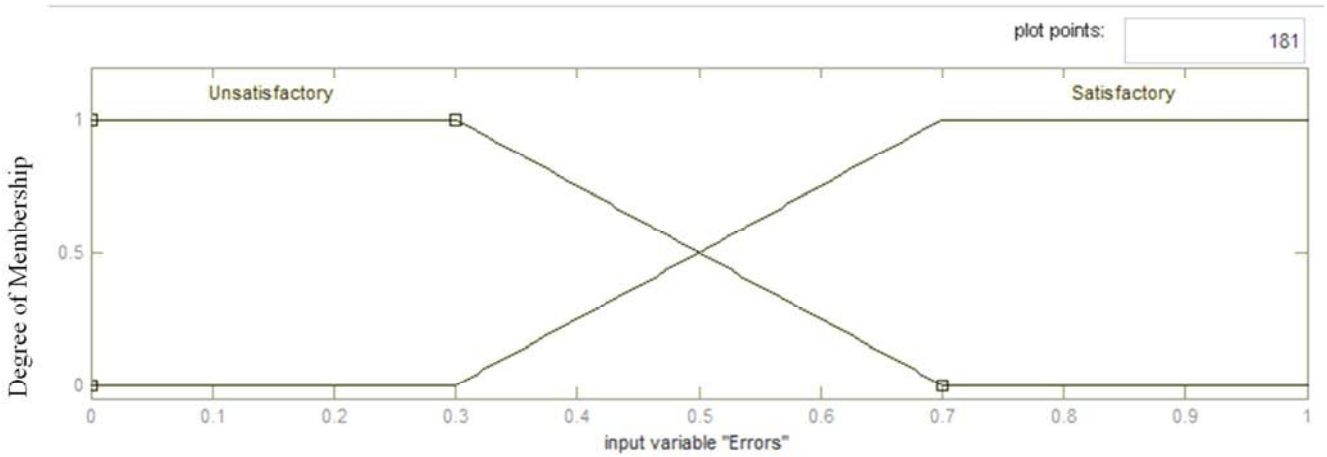

Figure 4. *Membership Function of the input variable "Errors".*

Webpage Speed Load: The scale for "Webpage Speed Load" indicator is between 0 and 1. If the result tends to 1 then it reflects an acceptable score. The benchmark of the speed within limit is 9.5 seconds according to international standard. Its computation is given as:

$$\text{Speed Load (S)} = \frac{\text{Total number of Links within speed limit}}{\text{Total number of links within speed limit } + \text{ links exceeding speed limit}}$$

Figure 5 illustrates membership functions of the "Speed Load" input parameter

$$\mu_{uns}(x) = \begin{bmatrix} 1, 0 \le x \le 0.3 \\ \frac{(0.7-x)}{0.4}, 0.3 \le x \le 0.7 \\ 0, \mathrm{x} \ge 0.7 \end{bmatrix}, \mathrm{u}_s(x) = \begin{bmatrix} 0, x < 0.3 \\ \frac{(x-0.3)}{0.4}, 0.3 \le x \le 0.7 \\ 1, 0.7 \le \mathrm{x} \le 1 \end{bmatrix} \quad (2)$$

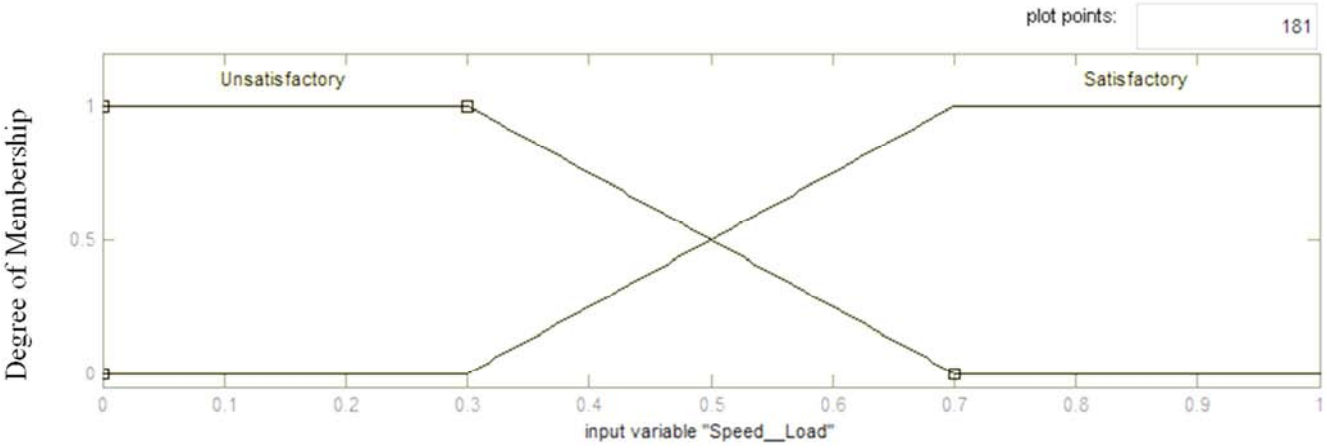

Figure 5. *Membership Function of the input variable "Speed Load".*

Website Quality *(Output)* Three linguistic terms are used to represent the output {poor, fair, high} with range from 0 to 1. Equations 3-5 reflect the membership functions of these three terms denoted by μ_p, μ_f, and μ_h respectively. Figure 6 represents the output of the associated membership function.

$$\mu_p(x) = \begin{bmatrix} 1, 0 \le x < 0.3 \\ \frac{(0.4-x)}{0.1}, 0.3 \le x \le 0.4 \\ 1, \mathrm{x} > 0.4 \end{bmatrix} \quad (3)$$

$$\mu_p(x) = \begin{cases} 0, \mathrm{x} < 0.6 \\ \frac{(\mathrm{x}-0.6)}{0.1}, 0.6 \leq x \leq 0.7 \\ 1, 0.7 \leq \mathrm{x} < 1 \end{cases} \quad (4)$$

$$\mu_p(x) = \begin{cases} 0, \mathrm{x} < 0.3 \\ \frac{(0.4-\mathrm{x})}{0.1}, 0.3 \leq x \leq 0.4 \\ 1, 0.4 \leq \mathrm{x} < 0.6 \\ \frac{(\mathrm{x}-0.6)}{0.1}, 0.6 \leq x \leq 0.7 \\ 0, x > 0.7 \end{cases} \quad (5)$$

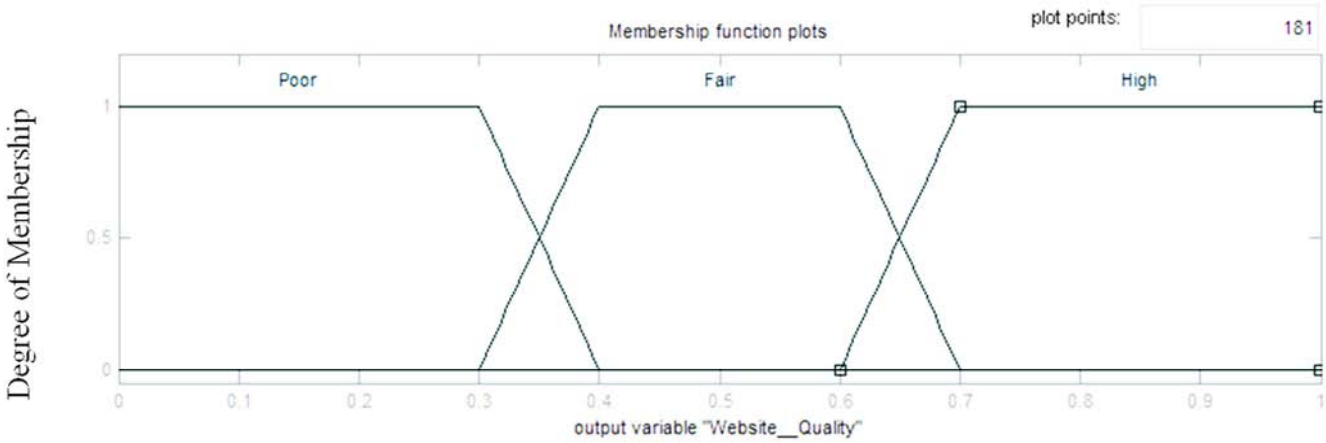

Figure 6. *Membership Function of the output variable "Website Quality".*

2.3. Set-up Fuzzy Rule Base for FWQAS

The inputs and output membership functions have been defined in section 2.2; the next step is to set-up a fuzzy rule base on the basis of the number of linguistic categories defined for each of the input parameter. If *b, e, s* denote the number of linguistic categories defined for broken links, webpage speed load and errors respectively, then the fuzzy rule base will have ($b \times e \times s$) rules. Therefore, this paper emphasizes eight 8 ($2 \times 2 \times 2$) rules of fuzzy logic. These rules usually take the form of IF – THEN rules and are obtained from human expert.

Listed below are the rules:

1. If (B is satisfactory) and (E is satisfactory) and (S is satisfactory) then (Q is High)
2. If (B is unsatisfactory) and (E is satisfactory) and (S is satisfactory) then (Q is Fair)
3. If (B is satisfactory) and (E is unsatisfactory) and (S is satisfactory) then (Q is Fair)
4. If (B is satisfactory) and (E is satisfactory) and (S is unsatisfactory) then (Q is High)
5. If (B is unsatisfactory) and (E is unsatisfactory) and (S is unsatisfactory) then (Q is Poor)
6. If (B is unsatisfactory) and (E is unsatisfactory) and (S is satisfactory) then (Q is Poor)
7. If (B is unsatisfactory) and (E is satisfactory) and (S is unsatisfactory) then (Q is Poor)
8. If (B is satisfactory) and (E is unsatisfactory) and (S is unsatisfactory) then (Q is Poor)

2.4. De-fuzzification of the Output for FWQAS

However, since the fuzzy rules have been stated, the next step is to use a standard fuzzy union to aggregate the membership functions of the three parameters based on the fuzzy rules and defuzzify the output using centroid method. This gives a crisp output value which is the website quality rating for the website being assessed.

Figures 7 and 8 depict the architecture of the Fuzzy-based website quality assurance system. The architecture is divided into four layers, which are:

a. Layer 1: User enters Website's URL
b. Layer 2: The highlighted components are checked for on the website (Broken links, errors, page load speed)
c. Layer 3: Fuzzy System absorbs the values and processes them
d. Layer 4: Rates the website as either, poor, fair or high quality

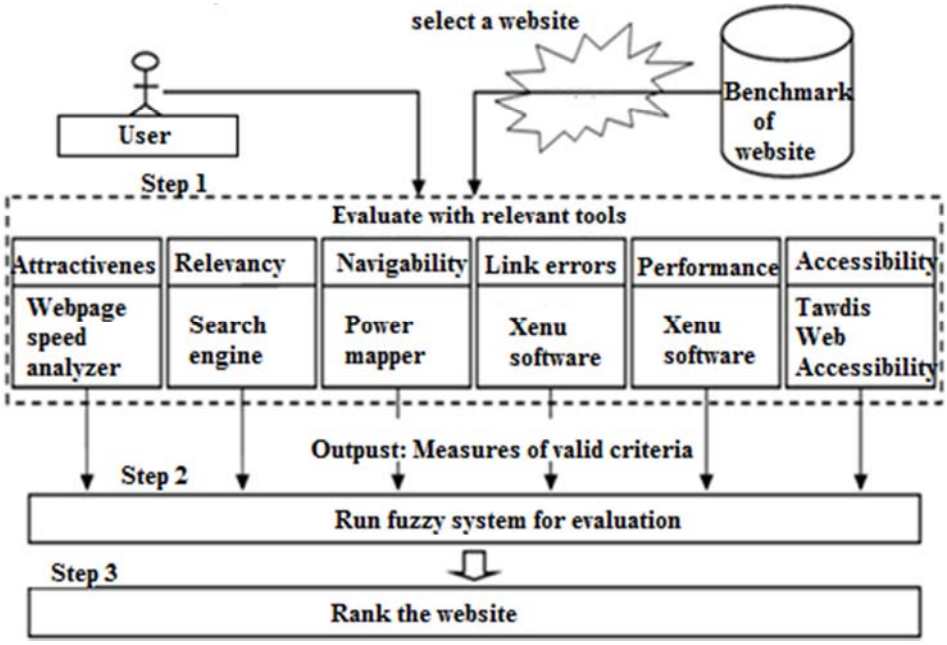

Figure 7. *Architecture of FWQAS traced from Fuzz-web.*

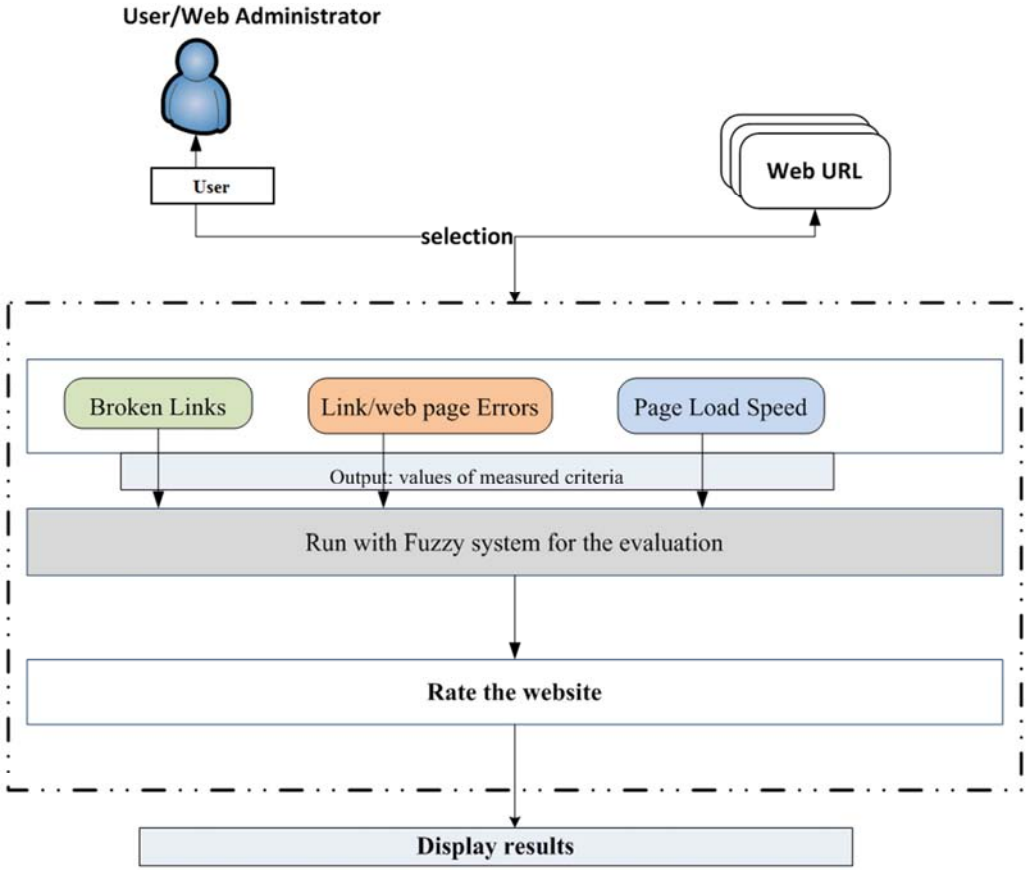

Figure 8. *Architecture of FWQAS.*

3. Implementation g and Results

Below are the screenshots of the developed system illustrating how the fuzzy-based website quality assurance system works:

a. Main page Overview

Figure 9 below shows the welcome page of the website quality assurance system with a major menu "Home" on the menu bar.

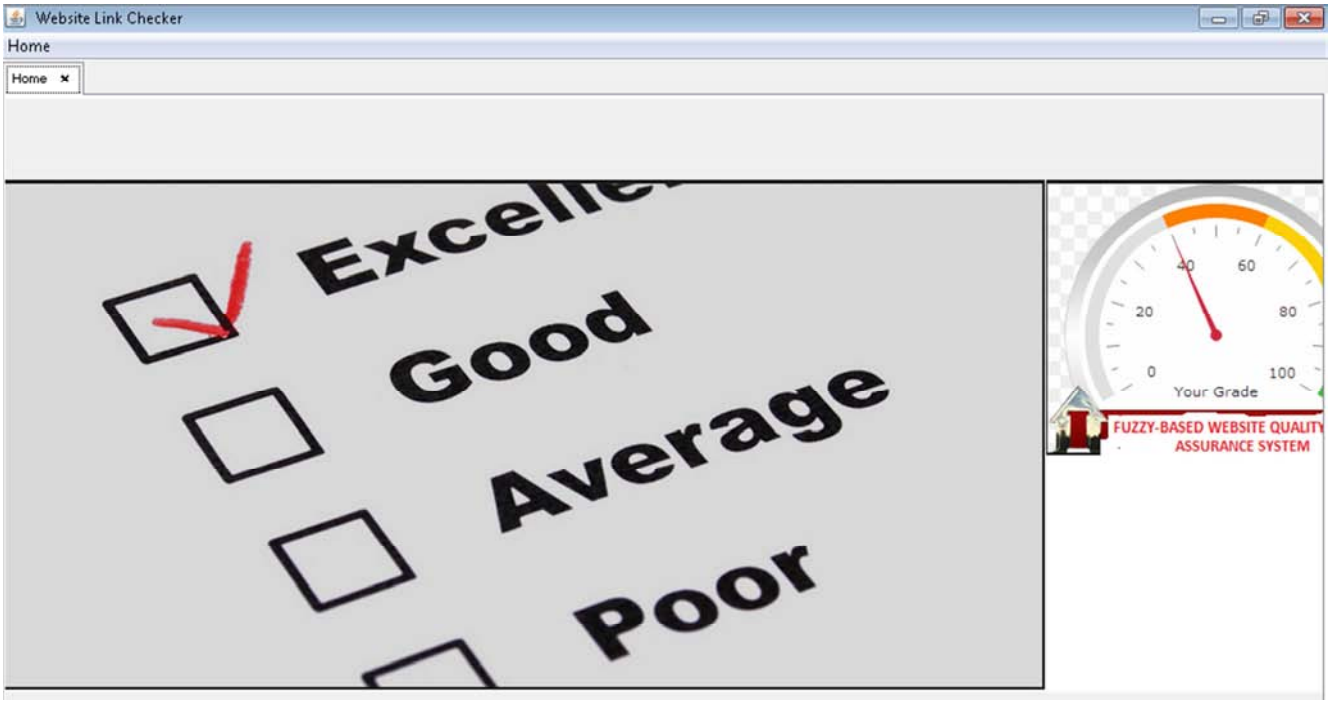

Figure 9. *Main page of the FWQ.*

b. Menu Bar

In Figure 10 below, the only menu on the menu bar is "Home" which has two submenus "check a link" and "exit".

Figure 10. *Menu bar.*

When the "check a link" submenu is clicked, it takes the user to another page that will allow for a website address to be entered and analysed while the "exit" submenu terminates the program when clicked on.

c. Check Link Page

Figure 11 shows the result of each link checked.

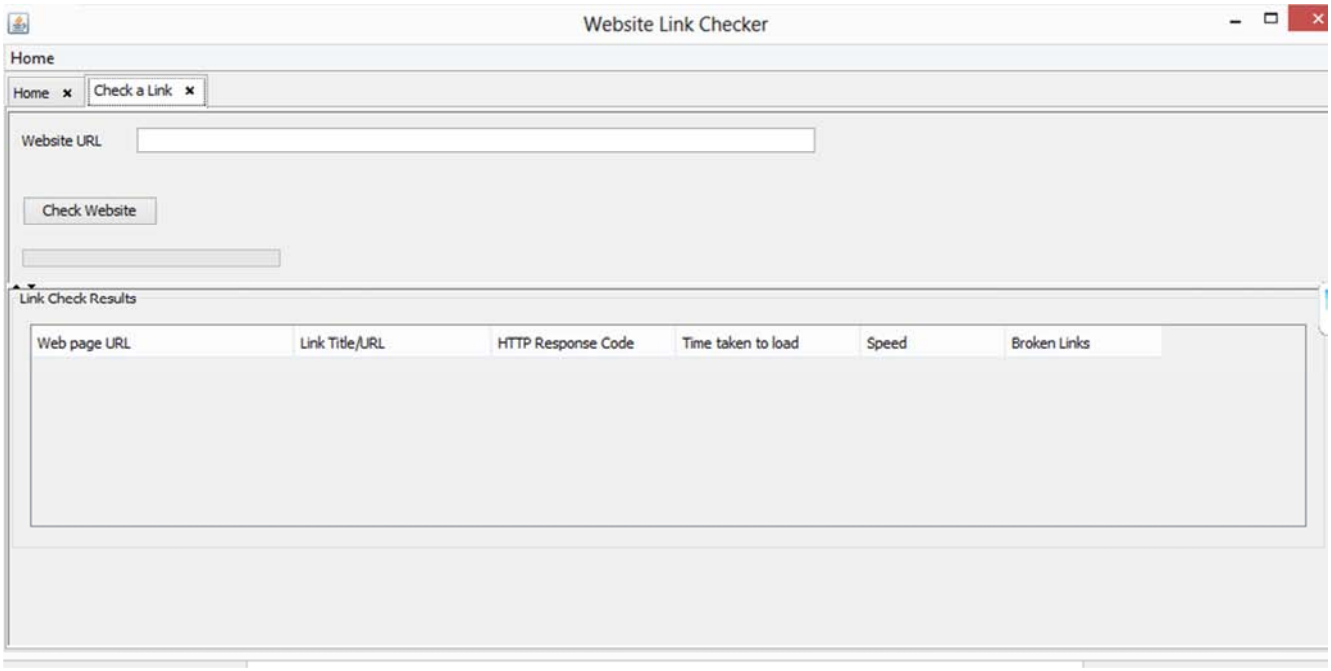

Figure 11. *Check Link page.*

The "Check Link page**"** consists of a textbox for entering the website's URL by the user, a "check website" command button; that when clicked on, if the URL is valid, the system initiates a connect to the index page and carries out a depth-first search for the first link reached to link to the last child link. Also, on this page, is a table for displaying the results of the links checked.

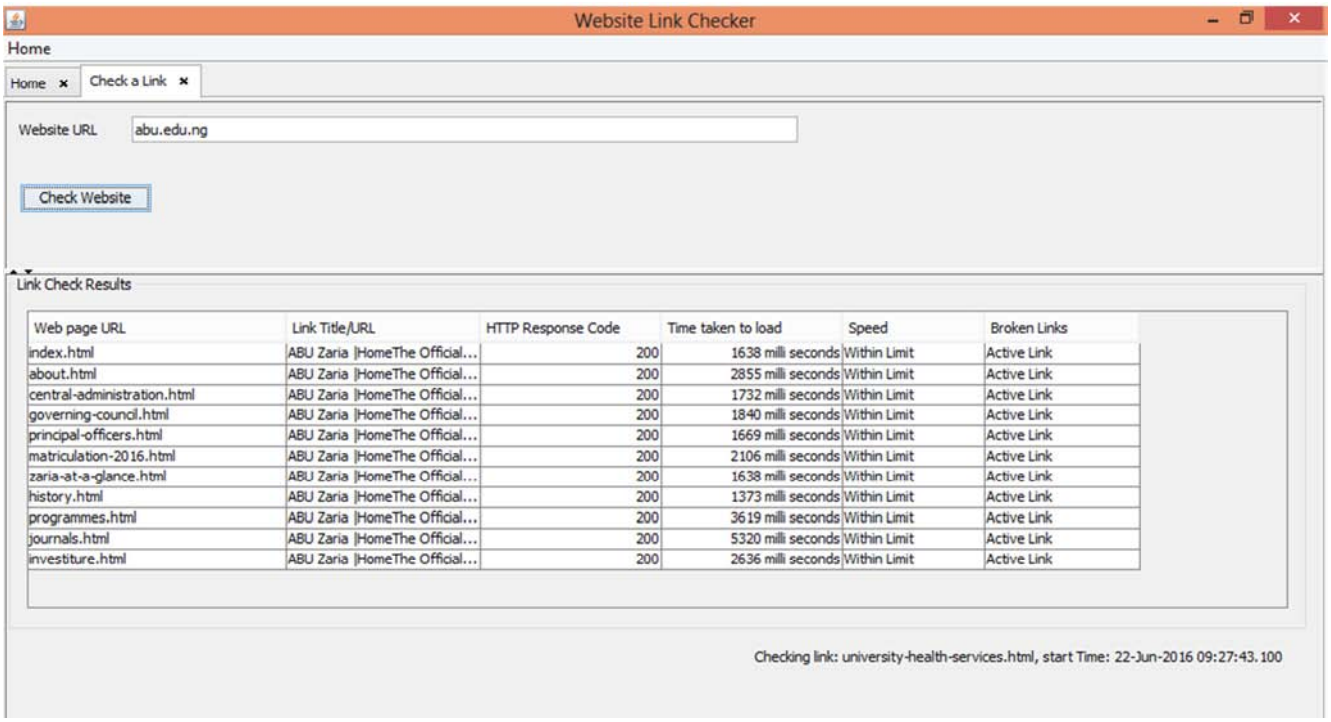

Figure 12. *Results of individual links checked.*

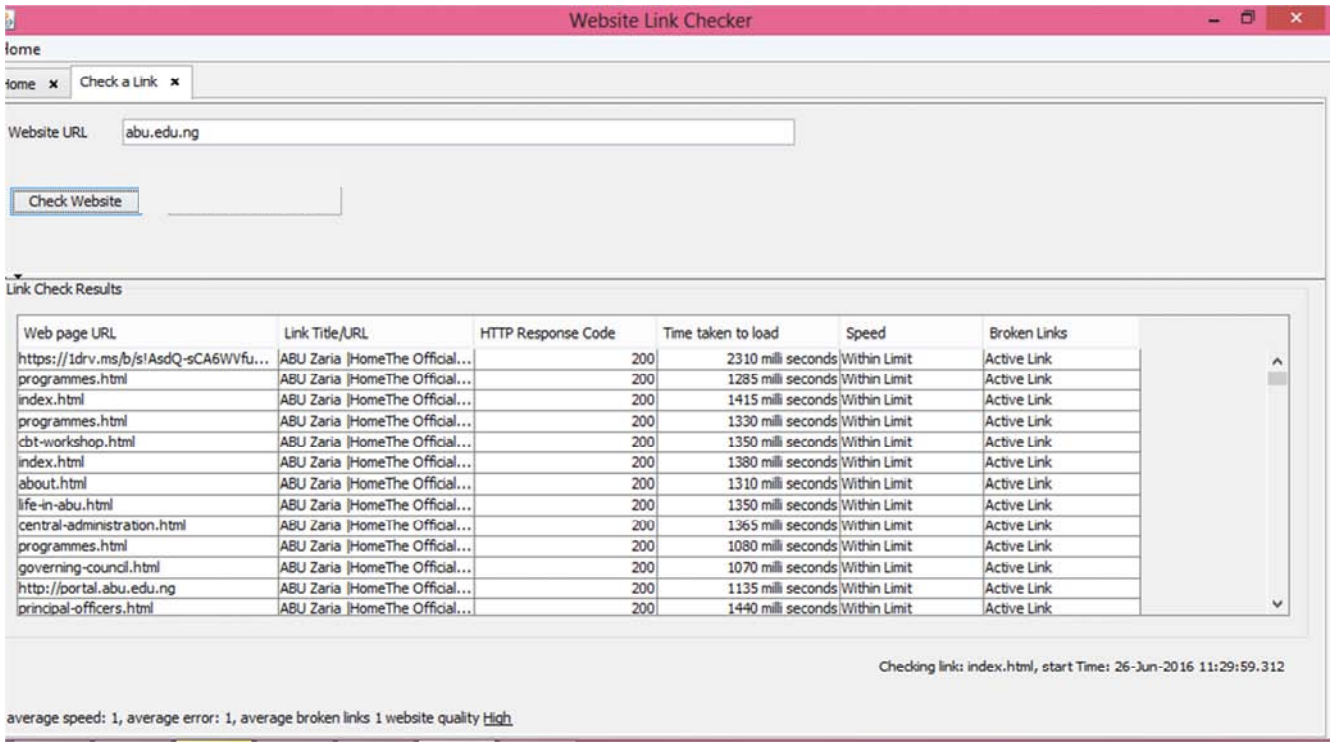

Figure 13. *Overall result of links checked displayed.*

The following parameters are checked Web page URL, Link title/URL, HTTP response code, Time taken to load, speed and Broken links for each link accessed. The Web page URL column displays the website address / URL of each webpage within the website that is accessed. The HTTP response code column displays the response code currently on the webpage accessed. The Link title/URL column displays the title / name given to the webpage accessed. Java measures time in milliseconds, so the "Time taken to load" column displays in milliseconds the time taken for the webpage to load, please note, a very stable internet connection is needed to avoid unnecessary delay in the time taken for webpages upload. The Speed column displays "Within limit" if the time taken for webpage upload has not exceeded 2 seconds. The Broken links column displays "Active link", if the link being accessed can be opened and "Broken link" if the link cannot be opened. Every link currently checked is displayed on the status bar located at the bottom, right-hand side of the "Check Link Page" and the results displayed in a tabular form on the same page (see figure 12 for visibility). When all the links in the website have been checked, the system takes as its inputs the results from all the individual links checked and applies fuzzy logic to compute the overall rating of the website. An example is shown in Figure 13.

4. Conclusion

The major contribution of the fuzzy-based website quality assurance system is to provide a simplified system that can assist web administrators towards ascertaining the state and quality of websites at any point in time and to be proactive in making necessary amendments to such websites with a view to guaranteeing good experience for visitors navigating through the said websites. The proposed prototype, FWQAS has shown that an assessment system can be self-sufficient devoid of dependence on external evaluation tools before performing its task. This paper has routinely resolved the objectives enlisted earlier having demonstrated a simple website quality assurance system that successfully: reports broken links; webpages load time; HTTP response codes to ascertain if there are errors on the website; as well as rates the quality of the website.

The following areas may be considered for future work:

a. The system design and implementation may be improved by including more vital parameters for assessing the quality of websites;
b. The system could be improved to give deeper analysis of the assessment results and also suggest solutions to the problems identified;
c. Improvement may be made to allow users enter more than one website URLs at once thereby allowing for the assessment of more than one website at a time.

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