



Web Engineering: An Engineering Approach for Developing Web Applications

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Abstract: To perform a runtime process in daily activities the software based system are playing very important role in facilitating effective completion of day-to-day activities. The enterprise world is offering products, communicating with prospective customers using information technology and web software applications for automating a business process is different than the traditional software development process. This research work highlights the difference between the traditional software development approach and web application development approach. The research work has made an effort to explain the issues a developer faces while developing a web application.

Keywords: Software engineering, web engineering, web application

I. INTRODUCTION

Since the dawn of technology in general and software driven system in particular has started its imprints in vital fields of both public and private sector in twentieth century. No one at that point of time would have expected that these computer based systems will become life supporting projections of present age. Since then there has been a tremendous change in these systems to make them more beneficial, human friendly and effective. The most challenging aspect of these automated computer based systems was the software component which acted as the part of the whole system to make it as a working system. Since the inception of technology both hardware and software has been in continuous improvement in their implementation, workload processing and other related characteristics within the domain. Software as we all know is the backbone for hardware management, rather it is the software which enables hardware to represent different frameworks, different work modules, different technique and patterns.

In layman language software is a group of related programs designed for performing some specific operation and in technical perspective it can be said that software is an integrated system of modules, each module is designed again with integrated technology to facilitate the candidate organizations with the functions for what it has been developed for with efficient, effective, reliable robust and user friendly characteristics. The development of these software driven systems has been in practice right from the dawn of computer assisted systems. Since then there had been different processes or techniques being implemented to develop these software systems. There was no proper standard that was being followed by different development people across geographically distant locations. All the developmental process were human-centric, where the development process was carried out by different software developers based on their willingness, experience and understanding. This traditional way of developing software system was efficient at small scale development and where the size of the developmental team was limited to very few people.

The traditional software development strategy was quite acceptable, widely used and was relatively performing good for small & less complex software development projects. With the rapid transition in software age the dependence on software driven systems has almost grown exponentially which has resulted in software driven systems becoming critical in their functioning domain resulting in increase of its importance in all sectors of mankind. The complexity of these software has grown at a very fast pace which has resulted in generation of huge scope of using computer based software systems in every activity to facilitate the effective and efficient completion of a task. This has led to huge demand for development of software driven system with more complex nature[1].

Keeping the demand and complexity of software driven system to be developed in mind the software development process needs to be addressed with professional development instincts. Traditional software development strategy was kind of rudimentary approach for development and inviting chaos to happen. In modern software development wherein the people generally experts in their particular domain of development were grouped in different group to develop an efficient system. The loopholes that were glorified in this traditional development process are listed as;

- The development of the complex system requires more people to render their services hence, proper management and delegation was required.
- The team size grows, personal discomfort was cited among the team members, hence required proper communication and motivation.

- The task assigned to an individual is sometimes not from the area of interest which results in less motivation and reduces the productivity of web development.
- Each team member considers his/her own way of development to get the assignment done. Proper time and resource management was least bothered hence, proper way or standard framework needs to be established to optimize resource utilization.
- The overall development process was unorganized, miss-managed, ambiguous, less productive, more failure prone, unpredicted budgetary. Hence proper development system needs to be designed to cater these characteristics.
- No quality parameter was obtained with satisfactory results. Hence needs for proper quality in management of the system to obtain optimum reliability, efficient, easy maintainable, robust, less failure prone and secure system.

The software development issues listed above have become bottleneck area in software development process. Therefore, the need of the hour is to address these issues in order to mitigate e their impact on software development process.

In 1968, Margaret Hamilton first coined the term “software engineering” and this term was publically glorified in world’s first software engineering conference, sponsored and managed by NATO[2,3]. The main perspective of this conference was to come with a standard framework or best practices for software, it was the gist of this conference which later became the blueprint for “how to develop software”. This was the first software engineering developmental framework designed by a researcher [4].

The main aim of designing a separate discipline for software engineering was to facilitate the software development industry with a standard framework of performing various developmental activities in a scientific manner in order to avoid software crisis and to make the software development process versatile.

In 1984, Software Engineering Institute (SEI) was established by Watts Humphrey. The fundamental purpose of SEI was to frame out the basic, systematic, rigorous, universal, acceptable, efficient set of preliminaries to develop software projects with acceptable levels of “quality of Service and Assurance”[5]. Software development life cycle was built for carrying out any software development work. The SDLC had the impression acquired from system development life cycle way back in 1984. With the development of technology in both implementation and behavior, there has been a tremendous evolutionary change in SDLC to obtain better results from limited resource utilization. Apart from different developmental models in SDLC and the inception of World Wide Web (WWW) and dependence on interactive internet communication there was literally a revolution in software engineering. The behavior and importance of these WWW based applications surged to such an extent that the software development community had to rethink over the developmental issues of these applications in-line with conventional software development methods. It was later concluded to have a separate discipline for these applications, hence “Web Engineering” was introduced to develop, implement, and maintain web specific applications also called as web application.

II. SOFTWARE ENGINEERING

As software has become an inevitable perspective in different working domains of serviceability, the criticality of software is a pivotal and sensitive issue to handle for example a life supporting equipment used for survival of human life. While developing a software program problems like budget, cost, time-overrun, maintenance, quality, reusability, satisfactions are the key challenges which need to be explored during software development process. If any these characteristics result in negative behavior the whole software development process might lead to failure. There have been many definitions from different authors for software engineering, in 1968, the year in which first software engineering conference was held, Fritz Bauer defined software engineering as “the established and use of sound engineering principles in order to obtain economically developed software that is reliable and works efficiently on real machines” [4]. Later IEEE precisely defined software engineering as “the application of a systematic, disciplined, quantifiable application approach to the development, operation and maintenance of software, that is , the application of software engineering to software” [1] .

This systematic approach, “software engineering” is a layered technology that is not an individual activity which constitutes software engineering rather there are several discrete activates working in collaboration with each other to perform the software development process. The most acceptable Layard approach of software engineering has four layers as tools, methods, process and quality factor for each layer there are different criterion which are implemented to check the correctness of these activities[8]. The software engineering has vast scope of applicability in development of different software driven products like system software, application-software, real-time-software, embedded-software, e-commerce, integrated systems, biomedical engineering and scientific software’s to name a few. Most of these software engineering products were either standalone projects or the projects supported to work within fixed contours of an organization.

In late 1980’s and early 1990’s WWW was used to interconnect the different patterns of information and disseminate it or make it accessible from within the organization from geographically distinct areas. The software development process using conventional software engineering practices to develop web applications

was difficult. The most predominate problems faced during the development of these web based applications were;

Table 1 : Problems faced during the development of web applications

i. Availability	ii. Performance	iii. Integrity
iv. Unpredictability	v. Motivation	vi. Availability
vii. Accessibility	viii. Synchronization and concurrency	ix. Network load management
x. Scalability	xi. Content management	xii. Control flow
xiii. Continuous Maintenance	xiv. Real-time importance	xv. Transaction management
xvi. Aesthetics	xvii. Navigation	xviii. Operability

All the above listed are the popular issues, which were raised for the of web engineering as an individual domain to develop web applications.

III. WEB ENGINEERING

The history of emergence of web engineering has its roots deeply related with the inceptions of World Wide Web (WWW) in 1989 by Tim Berners-Lee [9], a pioneer at CERN. This WWW is popularly known as Web, which is the subsidiary platform for establishing multipurpose platform technology in order to run the software application anywhere with basic hardware and installed operating system. With the progress of time the ubiquity of web based applications have almost taken control of all the activities which were supposed to deliver their services via inter-network. The scope and dimensions of web based applications increased at rapid pace, leading to increase in challenges faced by software development industry and increased failure rate.

The activities carried out to develop web applications were based on conventional software engineering approach which did result in increase in problems faces in the development of web applications. As the risk of failure increased the reliability of the approach was very less which led to cost over-run, poor quality and improper resource utilization. With the increase in problems faced while using traditional software engineering approach for web application development. It was proposed that there should be separate discipline, developmental framework and other related umbrella activities for the development of web application. After analyzing the drawbacks observed during the ad-hoc web application development process the web engineering by-and-large have undertaken all such developmental activities like conventional software engineering. Web engineering is also an effort to develop web application by integrating efforts, specifications related to certain developmental initiations, designing, developing and implementing web application in a systematic sequence.

It was also observed that the misnomer regarding the web applications that people consider web applications as a simple program with some beautiful design features and hypermedia but the reality is that there is more depth in web applications development than visual design and user interface. It involves planning, web architecture and system design, testing, quality assurance and performance evaluation, and continuous update and maintenance services of the software system as the requirement [10]. Web engineering is a potential solution for the development of applications which are required to execute and run on web based architecture to provide optimum performance, security, cost, scalability and maintenance. Web engineering uses scientific, engineering, management principles and systematic approaches to successfully develop, deploy and maintain high quality web software system [9]. The main aim of web engineering is to improve quality, optimize maintainability, controlled development and scalability of web applications in order to meet the customer requirements with higher levels of satisfaction.

IV. WEB APPLICATION

The most fundamental aspects which make web application to act different from the conventional software is the implementation by which the web application is deployed, implemented to perform its specified objective, standardized, developmental design parameters and other aesthetic characteristics results in higher acceptability. This web application consists of both the information content and the requisite technology framework to support its dissemination that is technically called as web hypermedia or web software application. A more precise definition on technologies and standards of the W3C that provides web specific resources such as content and services through a user interface, and a web browser. The definition of web application clearly delineates that the technology tier in addition to GUI of web application as well.

The current scenario of web application is that, almost all the organizations whether public or private, small or big have switched to render their services through WWW using web applications. Due to this usability and popularity of web applications are delivering its service in critical and sensitive areas of society like health sector and other business management processes. Due to this exponential growth of web application usability and dependence, the complexity, criticality, QoS, security, platform independence have become the main areas of concerns for the sophisticated development of web applications with effective and efficient results [10]. It is characterized by arranging the information into small sized blocks with links either in the form of intra-links or

interlinks to the content, anchors, access containers for designing navigation pathways and the presentation of the content within the web application. The content that is displayed on the web application by hypermedia is designed by implementing the web technologies like HTML, DHTML, XML, java Scripts, JSP, Servlet and multimedia controls. For the development of overall web hypermedia application, skilled people like technical writers, artists, designers and the end-user.

V. WEB APPLICATION CATEGORIES

The software applications that are designed on web architecture to deliver service as application require all the core technologies which are required to run simple web applications like information systems, reservation portals, knowledge base, and biological gene-pool to name a few web applications. They can be accessed from any platform irrespective of geographical locations.

Web applications are dynamic in complexity; each web application has a specific challenge to address, purpose to cover and scope to incorporate different but related objects. However, it is very tedious to have same pattern, size, and complexity among the different web applications to be developed, because web applications characteristics of change in field of scope, degree of complexity and functions. A web application can range from a small static information page with some information representation to a complex web application used to handle the corporate transactions with heavy load to massively complex rather critical scientific decentralized web applications used by organizations like NASA, Nuclear Proliferation, CERN and Proton Colliders. Different researchers have identified different categories of web applications depending on different parameters under considerations and some of the popular classification of web application is given below;

Table 2: Categories of Web applications based on pattern[11]

Category	Description example
Informational	Brochureware sites that just present information
Delivery system	Download content (e.g., plug-ins)
Customized access	Access to selected services via a customized interface
User-provided content	User provides content, such as by filling in a form to register for a seminar
Interactive	Two-way interaction between sites, users, and resources such as a company and its suppliers
File sharing	Remote users collaborate on common files such as schedules
Transaction oriented	User buys something such as travel tickets or performs on-line trading
Application service provider	User rents an application such as a virus program or disk backup facility through a service provider.
Database access	User requests access to database information such as looking up a catalog of parts
Document access	Access to on-line documents, such as corporate standards
Workflow oriented	Access is based on a process or workflow such as order entry automation
Automatic content generator	Automatic content generator by robots or agents that scour the Web for information, such as the best price on a car

Table 3: Categories of Web applications based on functionality [12]

Category	Description example
Informational	Online newspapers, product catalogues, newsletters, manuals, reports, online classifieds, online books
Interactive	Registration forms, customized information presentation, online games
Transactional	Online shopping (ordering goods and services), online banking, online airline reservation, online payment of bills
Workflow oriented	Online planning and scheduling, inventory management, status monitoring, supply chain management
Collaborative work environments	Distributed authoring systems, collaborative design tools
Online communities, Marketplaces	Discussion groups, recommender systems, online marketplaces, e-malls (electronic shopping malls), online auctions, intermediaries

Table 4: Categories of Web applications based on complexity and development history parameter [13]

Category	Description example
Document Centric	Static homepage, web radio, company web site)
Interactive	Virtual exhibition, news site, travel planning
Transactional	online banking, shopping, booking system
Workflow based	E government, B2B solution
Collaborative	chat room, E learning platform, P2P-services
Portal oriented	community portal, online shopping mall, business portal)
Ubiquitous	customized services, location aware services, Multi platform delivery
Semantic web	Knowledge management, syndication, recomender system)
Social web	web logs, collaborative filtering, Virtual shared workplace
Interactive	Virtual exhibition, news site, travel planning

VI. WEB APPLICATION ARCHITECTURE FRAMEWORK

Architecture and framework terms are used interchangeably to represent the basic organization or pattern of the set of activities, processes, objects and technologies to build a web application system to obtain the desired

results with effective and efficient parameters. There are many definitions available in the literature to describe the basics of architecture [14,15 16, 24, 25]. Architecture of a software system consists of its structure, the decomposition into its components their interfaces and relationships. It describes both the static and the dynamic aspects of web based software system in order to be considered as building framework and flowchart for undertaking software new web application development process [17]. We can also define architecture as a basic “framework of change” that is software architecture forms a framework in which a web-based software system can evolve [18].

Requirement engineering and agile development of the web application needs the architecture to change as either the requirement elicitation is not clear or the resources needed to develop the web application are not sufficient enough to perform the web application development process on the underlying architecture. Therefore, the basic architecture is changed as per the need of web based software development team. The changing nature of the architecture has lot of vulnerabilities which may result in failure of development of web application process. The budgets can tumble as web applications development process is dynamic; Henry Jacobson 1999 prescribed a list of factors that may directly or indirectly influence the behavior of web application development[19]. There attributes are represented by diagram as shown in figure 1 ;

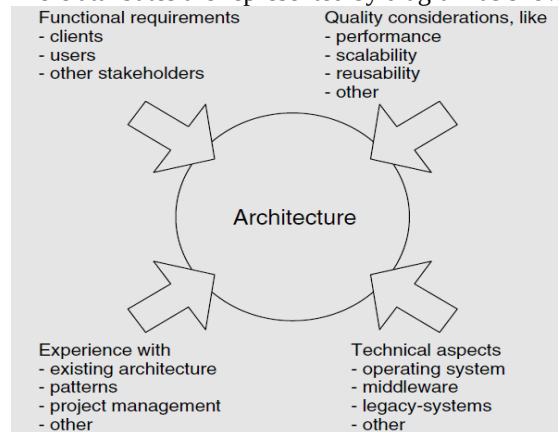


Figure 1: factors influencing the development of architecture [19]

Web application architecture not only specifies set of actions and factors required for the development of successful functioning and Quality of Service (QoS) delivery of a web application rather ensures that the attributes like changeability, reliability, performance, scalability, security, integrity, availability are maintained to deliver their service effectively and efficiently[20, 21, 22]. This is now mandatory to establish or design a generic architectural framework which will be universally acceptable and in addition to this will ensure all the parameters which are responsible for successfully, efficient, effective, secure and maintainable web application development and framework. The generic web application architectural framework consists of interrelated and interconnected set of components. The organization of the components is maintained in a fashion that whole architecture is triggered to address the basic request from the client, which is later processed by the corresponding components of the architecture to generate the valid response. The basic generic framework of web application architecture is represented in figure 2 below;

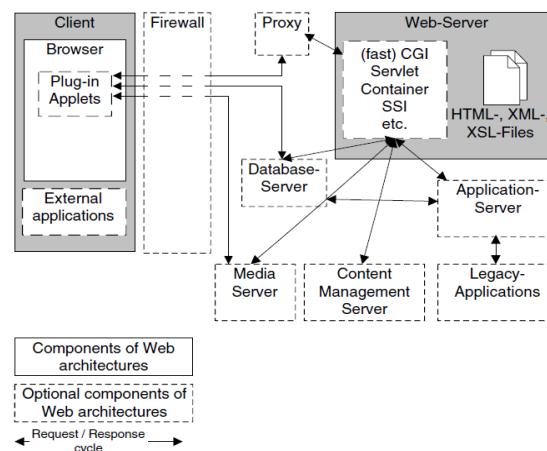


Figure 2: Generic components of Web Application Architecture

VII. WEB APPLICATION DEVELOPMENT FRAMEWORK

Every process has to function within the limited set of parameters with fixed constraints to span their boundary values. As nature has tendency to be dynamic and for every development we need to acquire the set of

preliminary requirements which are required for the initiation of web application development process. It is not necessary that all the requirement needed for the proper development of the web application are readily available before the development process takes its job rather the requirements of the web application might evolve over the development time because of uncertainty in some functionality behavior. The need to change the state of dependents to reach the acceptable or optimal levels of satisfaction the most critical factor is cost estimation, timeliness are very important while developing the web application. To overcome these issues of web application development and to mitigate their impact on the development of web applications, development community especially SEI has proposed a blueprint to design a web application process development to anticipate all the challenges, mitigate them and deliver the best possible product within the best levels of acceptability, quality, design serviceability, control flow, aesthetics and budget [23]. Most of the web application development projects conceived is usually delivered by adapting incremental development. To avoid developmental issues and to optimize requirements engineering activity, quality assurance and security should be acceptable in any web engineering framework used for web application development, and the same is expressed graphically in figure 3;

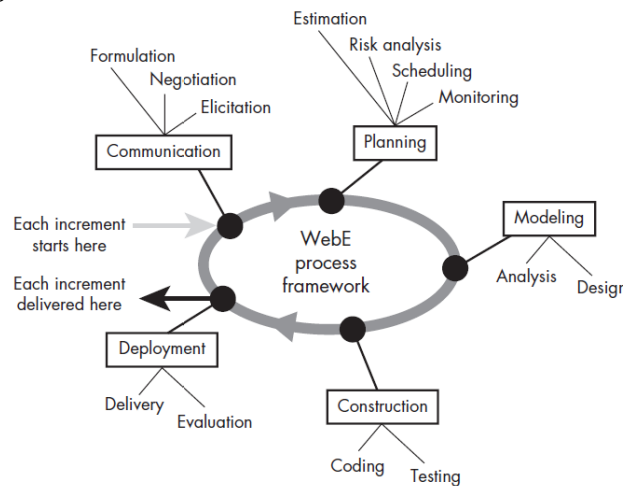


Figure 3: Web Application Development Process

VIII. TECHNOLOGIES USED FOR WEB APPLICATION DEVELOPMENT

After the popularity of web the technologies which were used as the main subsidies where refined and new technologies were introduced to get better service, usability and other related characteristics. The implementation of technologies for the development of simple static web application to massively dynamic web application noticed a varying change in both behavior and implementation. The most popular technologies used for development, deployment and maintenance of web application are enlisted in table 5A, 5B, 5C and 5D respectively [26, 27, 28, 29, 30, 31];

5A: Client Side Technologies

Technology	Description
Helpers and plug-ins	Adds functionality to web browser, helps in enhanced processing of multidimensional client requests, needs to be installed by client extended to. Plug-ins are permanently installed into the browser for optimized communication
Java Applets	Java programs, loaded dynamically into the browser, not persistently stored on a system. Loaded by web server, executed in a browser with JVM
ActiveX Controls	Standard COM component, designed to promote COM interfaces, Compiled into binary code , Stored into browser standard cache directory. Developed in an arbitrary language including java, Visual basic, C++,as long as COM and language complier meet respective specification.

5B. Document Specific Technologies

Technology	Description
SVG(Scalable Vector Graphics)	Image format, describes 2-D graphs in XML Recognizes three types of graph objects: vector graph, images and text. Support event based interaction and all kinds of animations
SMIL(Synchronized Multimedia Integration Language)	Represent synchronized multimedia presentations, Coordinates presentations of different media such as audio, video, text, image, presentational contexts. Random generators, slow motion, time lapse

XML- eXensible Markup Language	Capability of defining flexible data formats to exchange formats on web, homogenize heterogeneous environments, Doesn't dictate predefined markup with implicit semantics, well-formedness and validity properties
Namespaces	Used to avoid name collision with equally named elements in XML document
XML DOM(Document Object Model)	Introduced an objective oriented view on XML, Allows easy and intuitive processing of XML Created by XML parser Accessing of nodes in object oriented way
DTD(Document Type Definition)	Allows introducing specifically defined structures for an XML document. XML borrow DTD from SGML Easy to understand
XML Schemas	To overcome the limitations of DTD Capability of data type integration, reusability and XML formulation. Used to define pre-defined data types Supports user defined data types
XSL-extensible Styles sheet Language	Three parts; XSL Transformations, XPath and XSL-FO, Includes the standard to transform and format XML XSLT is a language, defines pattern and rules for their transformations XSL-FO defines formatting styles, represents only one of all possible transformations results for XSLT
XPath	XML path language Functionality to traverse an XML document Allows definition of new search paths
XSL-FO (eXtensible Style-sheet Language formatting Objects)	Represents a definition of media specific objects for various final representations, Not exclusively bound to visual media. Forms bridge between contents defined in media-independent XML & their platform-dependent output, e.g. PDF Document.

5C. Server Side Technologies

Technology	Description
URL handlers	Processes HTTP requests to deliver HTML pages, Identify the instances that process the request
Server Side Includes(SSI)	Simple mechanism for creation of HTML pages, Implemented by preprocessor for HTML pages which are integrated with web servers, Supports <i>include</i> and <i>exec</i> commands
CGI/Fast CGI (Common Gateway Interface)	Standardized interface between web server & application program to forward data in HTTP request to an application program, Languages available on the web server platform can be used, Limited scalability , FastCGI: parallel servicing of multiple requests
Server side Scripting	Introduction of ASP offered by Microsoft as server side scripting, PHP, Cold Fish and server side java scripts are represent the same category, Allows inserting file contents or output programs, No way of interleaving in the pre-processors control flow
Servlets	Invoked by URL to process incoming request and generate HTML response on fly, Run in special containers called as Servlets containers, Integrated with web server, Enhanced version of CGI, Servlets have multithreading capability, Concurrent processing of requests
Java Server pages	Simplify programming of graphically sophisticated HTML pages, Integration of java program code to create dynamic content. Runtime translates JSP into Servlets and then create corresponding HTML response
ASP.NET	Next generation of ASP, Server controls separates codes from content, Simplifying the design of dynamic pages, Supports implementation and use of web services, Development of distributed web applications
SOAP(simple Object Access Protocol)	Way for exchanging message on the basis of XML, Uniform message protocol, platform independent protocol, doesn't handle transporting message, referencing semantics or distributed garbage collections. Three parts: SOAP envelope, SOAP encoding rule and SOAP RPC representation.
WSDL(Web Service Description Language)	Common interface to exchange messages, Layout of function calls from user and web service, Composed of: <i>Core-elements</i> and <i>Extension</i> elements
UDDI(Universal Description, Discovery and Integration)	Helps clients and servers to trace each other, Users SOAP for communication, Allows to companies to offer their products and services by name, product, location and other criteria.

5D. Middleware technologies

Technology	Description
Application Servers	Closely related to concept of 3 layer architecture, Serviceability for processing of online transactions, Environment for the development and operation of component-based, distributed applications, Offers services like transactions, resource pooling, load balancing, naming. Supports specifications of J2EE, JSP, Java Servlets, EJB, CORBA etc.
Enterprise Java Beans	Represents component based architecture to develop, deploy, open platform –independent, distributed client/server applications in java, Implements session beans and entity beans, Run in a special runtime environment- the EJB container, Offers integrated services, transactions support and object persistence
Messaging System	Offer message based, asynchronous communication between distributed systems, load and availability of the system management, messaging systems are grouped into request/response and publish/subscribe communication

IX. CHALLENGES OF WEB APPLICATIONS

As web system is easily available system for the remote clients to access and execute their different tasks on respective web application through web browser. The unexpected and uncontrolled access of the web application may have to face the real challenges to withstand continuity of service. There are number of factors which may peep into the web and can make the web application process to behave differently. The access over the web application can be simple information accessing to performing transaction. An access can be accessing public contents and private content, so content management is delicate issues to bar access to specific content. There are numbers of challenges that can make users to doubt the credibility of web application. The people may reject the system hence all the resources incurred in its development can prove out to be waste of resources. Hence it is an aspect of web engineering to predict all the challenges and issues that might arise from the web application based system while being in service and needs to be properly addressed. Some popular issues being faced by web users are given in table 5.

Table 5: Challenges faced by web uses while experiencing web application

i. Ensuring security	ii. Concurrency and persistence control	iii. Data integrity and availability
iv. Performance, reliability	v. System shutdown or slow down	vi. Browser compatibility
vii. Integrating different technologies	viii. Debugging	ix. Cryptic error messages
x. Limitation of HTML for page layout	xi. Ensuring usability and maintainability	xii. Designing and implementation of UI
xiii. Configuration of server software	xiv. Authentication and authorization	xv. Data base design and connectivity
xvi. Aesthetics and navigation	xvii. Content design and management	xviii.

X. CONCLUSION

Due to the growing demand of web based software's (web applications) it was difficult to undertake the development of these web based software using conventional software engineering practices. So it was accepted that there should be separate discipline to deal with all the aspects, issues, technologies, development and other related domains paving way to web engineering as a separate subject to cater the demands required for the development, deployment and maintenance of web based systems. Separate developmental and architectural framework was established for efficient development and execution of web application Web application are platform independent and can be accessed from any individual from any distant location. This is not all what web application and web engineering is rather by growing complexity of web applications several issues arise and web engineers have to find the suitable counter mechanism to handle those issues so as there can be minimal user concerns. The future course of research is to study various techniques used for effort estimation for web application and to design the revised framework for estimating the efforts required for developing web application with minimal deviation between actual and estimated efforts.

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