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Development of a Semantic Web Framework for the Blind

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Abstract:- This research addresses some of the important issues related to web accessibility in the context of blind users. The problems of Web data accessibility and navigation for blind users have become an active research field for the past decade. Many techniques have been created to solve them, some are hardware-based and others are software based. Yet, the web is rapidly evolving toward the far-anticipated Semantic Web (SW): a revolutionary vision extending Web information with well-defined meaning so that it becomes more easily accessible by human users and automated processes. As a result, SW technological breakthroughs such as ontologies and semantic data description, as well as data representation and manipulation technologies (i.e RDF, OWL, and SPARQL) are being recently explored to improve data accessibility for blind Web surfers. This research, briefly explores existing studies targeting Web data accessibility for blind users ranging from traditional techniques (Braille output, screen readers, etc.) to semantically enhanced techniques (using Speech and alternative speech-based interfaces for human-computer interaction). A semantic web for the blind was designed and implemented using JAVASCRIPT, HTML, CSS, and MySQL. After the evaluation of the developed framework, the result of the research revealed that it has load-time as 75%, success ratio of 0.93, repository size of 65%, and CPU-time up to 80% and comparing it to the existing performance evaluation, it can be said that the proposed developed framework out performed.

***Keywords*:-** *Semantic; Framework; Blind; Web; Interaction*

I. INTRODUCTION

The internet is a vast resource that has increased the availability of information by stratospheric proportions; unfortunately, information availability is not proportional to accessibility. The internet is overwhelmingly visual and the advancement of multimedia on the web is not improving the situation [1]. Simple data retrieval operations that would be trivial to most users are comparatively complex for users who have a visual disability such as blindness or print impairment. Blind users rely on tactile auditory output to interact with computers; however, web pages are not designed with these access methods in mind. Users often find themselves overwhelmed by complicated methods in mind. Users usually find themselves overwhelmed by complicated pages that are bloated with non-cohesive information, lack structure, and are inconsistent with other pages on the same site [1].

Assistive Technologies (ATs) such as screen readers employ the underlying document object model (DOM) structure of a web page to narrate its contents to a blind user [2];[3]. Web developers must follow the W3C and other criteria while designing websites to guarantee that ATs perform properly. Unfortunately, due to a lack of understanding among web developers, this need is not being satisfied adequately, and as a result, a huge amount of web material remains unavailable to ATs and blind users. Web 2.0 has accelerated this trend by providing end users with web authoring skills [4]; [2]. Thus, the goal of ATs is to disclose such inaccessible webpage information using creative approaches and deliver them to blind users [2]. The compelling need for more user friendly products as well as the recent trends towards universal accessibility and greater usability of interactive applications is highly important [5].

The problems such as stigmatization, difficulties in web accessibility, and mobility are what motivated this research. Due to the continuity of the blind persons struggling with Web access as a result of the fact that most webpages are increasingly reliant on visual content and graphical design, even in the face of screen readers or talking browsers [6], and in the high informality of the declarative graphic representations that were used to represent knowledge and support automated systems is what brought difficulties in web accessibility and mobility according to [7].

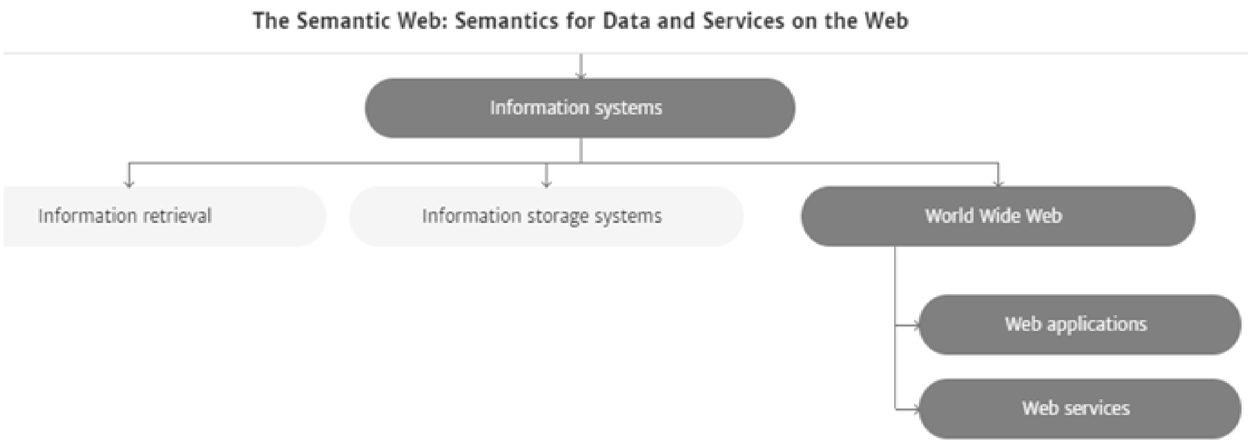

Fig 1 The Semantic Web for the Data and Services on the Web [8].

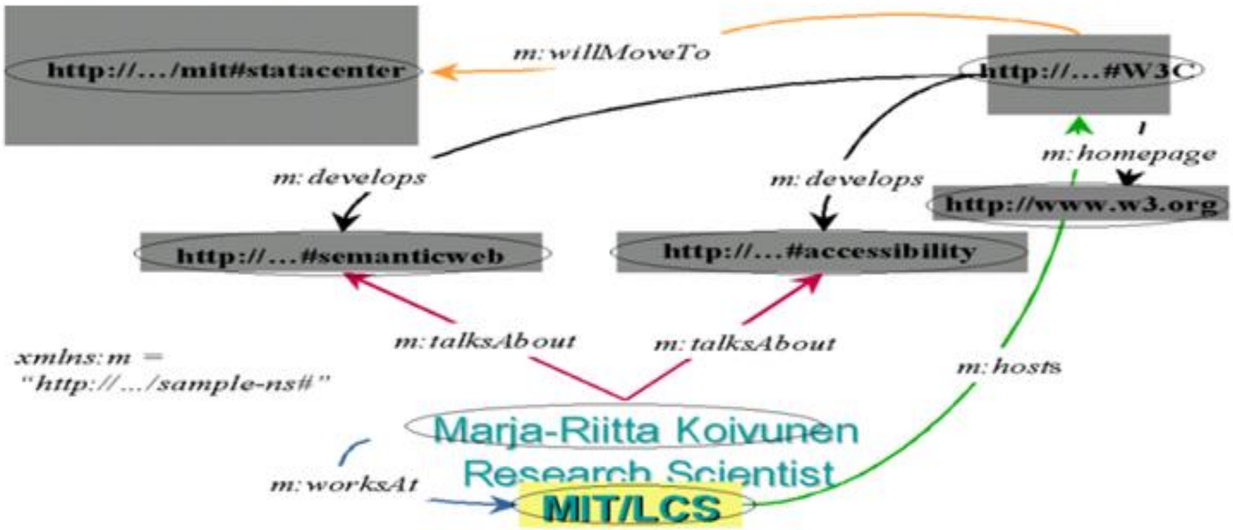

Fig 2 The Workflow of a Semantic Web [9]

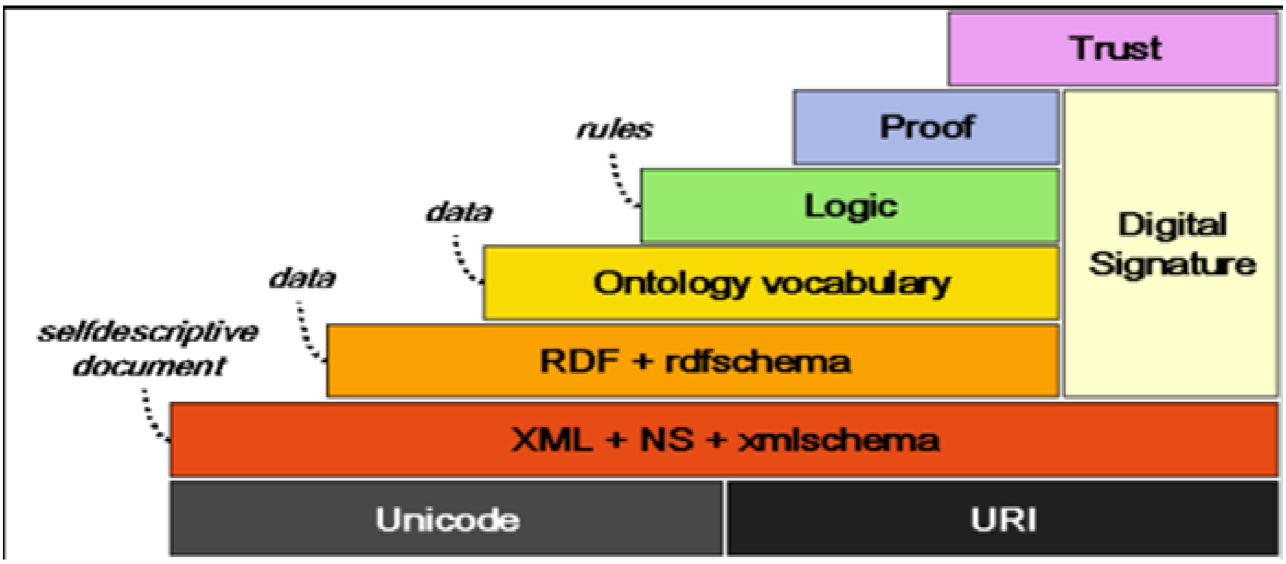

Fig 3 The Semantic Web RDF Core Ontology Repository [10].

The materials and findings of this research provides the awareness that blind users can surf the web. This was achieved by providing an alternate speech-based interface for human-computer interaction. This aids developers to incorporate speech recognition while designing any program to aid blind users and create the most realistic method of utilizing the Internet for their vital and routine tasks that will allow them to live independently and with dignity.

II. METHODS AND MATERIALS ADOPTED

The research evaluated existing semantic web systems and their techniques with a view to exposing their flaws through in-depth literature review. The literature review was followed by an analysis of how to apply better discovered features that will efficiently build a quality and easily accessible semantic web for the blind. A Javascript web-based framework which used easy simple setup rules and intelligent keyboard keys detection scoring to achieve high rates of internet usage among the blind. The semantic web framework designed for easy accessibility of the blind to world-wide-web incorporated knowledge, best practices and technology in mitigating the problem of stigmatization.

The developed framework incorporated the wide use of ontology, meaningful semantics, suitable programming language and best database tools for implementation to ensure that the success ratio, CPU-time and load time are not less than one. In other words, the proposed framework used SAT which provided a common interface for service providers (SPs) in order to register their services according to the descriptors supported by the proposed framework ontologies and integrating those procedures and techniques that could be easily adopted under the current computing environments with affordable consumption of resources.

The framework developed is then tested, validated and reviewed through its functionalities for future and improvement.

[11] explains how the existing tools for disabled users are ``adaptive in nature'' so the methodology that would be used, would be adaptive methodology whose primary purpose is to extend an existing piece of software to incorporate some new functionality that improves disabled user interaction.

➢ *Such Adaptations Can Be Categorized In Three Different Levels:*

- Alternative access adaptations extend an existing solution to provide support for specialist input/output equipment such as Braille displays or screen magnifiers.
- Information content adaptations involve modifying the representation of data to make it more accessible. Such an adaptation may extend html to make it more accessible to text-to-speech engines by adding further descriptive tags to the visual elements of a page.
- User Interface adaptations involve changing the way users interact with an application in order to cater for the needs of a specific user group. Such an adaptation may alter a web browser to render web pages without images and with large text so that they may be easily read by those who are blind.

These adaptive approaches allow developers to take advantage of the pre-existing functions present in an application, which they would not have the time or resources to implement themselves. However, it can be technically difficult to adapt a piece of software to perform a different task to which it was originally intended, especially if the code is highly complex or proprietary.

➢ *Hardware Based Techniques*

These techniques provide the user with hardware interfaces using the universal language Braille[1] (used by 2 out of 10 blind people). These are implemented through devices like the Braille keyboard (data input) and *Braille display* (data output). Yet, such devices are generally expensive, and need to be mounted and configured manually on each computer system (e.g., PC, tablet, smartphone, etc.) to be utilized by the blind user.

Fig 4 Main hardware accessibility techniques for blind users.

The Braille system is a method based on tactile contact, widely used by blind people in order to read and write text.

➢ *Software Based Techniques*

These techniques can be implemented on any basic computer system and do not require special hardware:

- Speech synthesizers are software tools that transform text-based input into (human) speech output.
- Screen readers (e.g., VoiceOver (mac), YASR (Linux), Tiny Voice (Dos)) are software tools that attempt to identify and interpret what is being displayed on the screen of a computer: the text shown on screen is straightforwardly transformed into audio (speech) output, whereas images and other multimedia objects are confined to their alternative text descriptions which are transformed into speech.
- Talking browsers are internet browsers that transform an input Webpage into an audio (speech-based) output using speech synthesizers, providing some shortcuts (e.g., list of headings (insert+F6), list of links (insert+F7). While some of these tools have been shown efficient (such as WebTalkster, Word read, Browse-aloud, yet they remain confined to reading text-only input that appears on the screen.

While the above software-based techniques have been shown practical and efficient, they were designed to provide data output only (transforming and presenting data to the user in audio or sound-based modality). They do not however target data input.

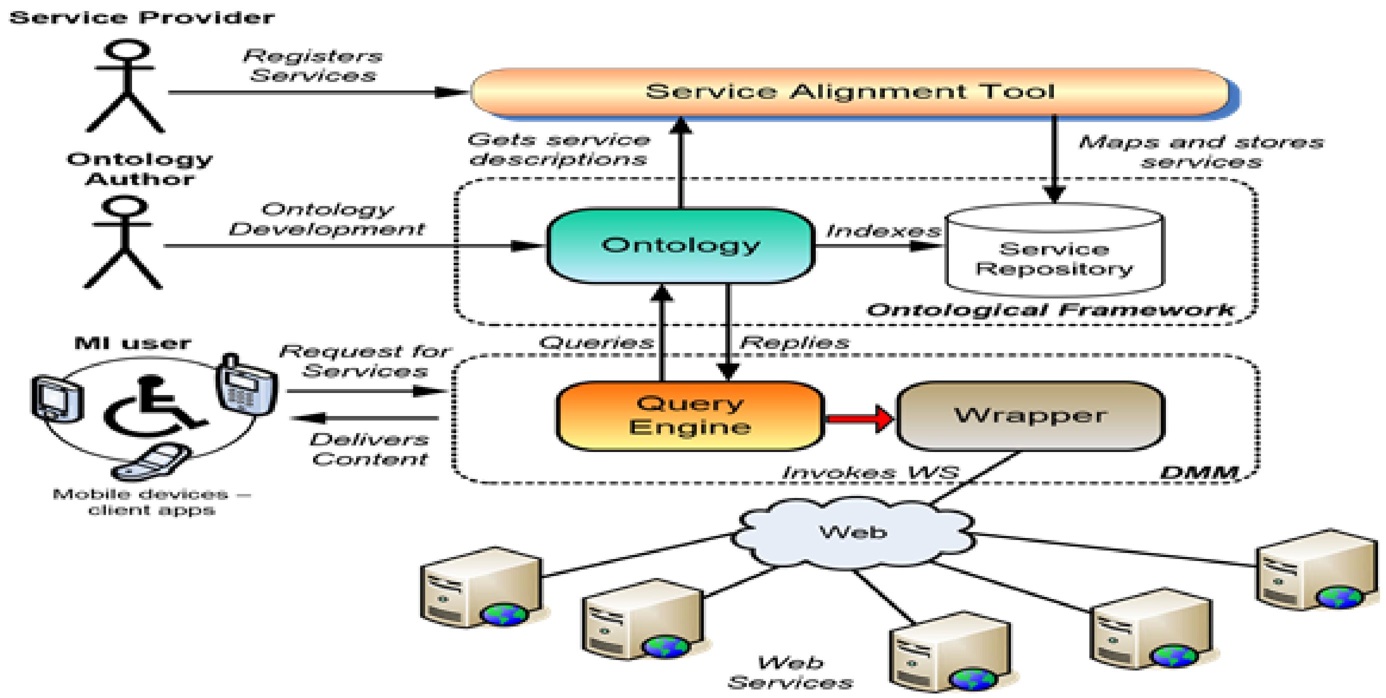

Fig 5 The overall architecture of the proposed system back-end system

III. IMPLEMENTATION

As soon as a request for service is launched by the client user application, the DMM submits a semantic query to the ontological framework in order to retrieve the appropriate service. The retrieved service is invoked by the corresponding wrapper via SOAP messages exchange.

The data management module (DMM) handles incoming user requests for services. The DMM listens to the request, decomposes it, searches for the appropriate services through the query engine and retrieves the service that best fulfils the user request.

➢ *In The Back-End System Architecture The Following Units Are Included:*

- ***SAT.*** This component provides a common interface for SPs in order to register their services according to the descriptors supported by the ASK-IT ontologies. As soon as a new service is registered, its location is stored in a service repository.
- The ontological framework consists of the overall ontology, which consists of a number of domain-specific ontologies and the service repository. An ontology author is granted access to the ontology in order to perform modifications on it. The service repository acts as an index of services, which are linked to the ontology. The structure of the overall ontology and the separate domain-specific ontologies are presented in below.

➢ *The DMM supports the following operations:*

- It manages incoming requests for services. It processes the requests via a query engine that submits the appropriate semantic queries to the ontological framework. After processing the DMM request, the ontology replies by a list of retrieved services and their locations.
- It also performs invocation of real WSs via the corresponding wrapper, a client application, which is aware of the valid mappings that should occur between real WS data types and the ones defined in the ontology. In this way, the wrapper becomes capable to invoke the real service when receives a request for service invocation in the common ontological format. It finally wraps content returned by the previously invoked WS and sends it back to the user application in the common ontological format.

Content exchange between DMM and real WSs is performed by appropriate messages defined in the Simple Object Access Protocol (SOAP).

➢ *The Service Alignment Tool*

Service alignment is the process of registering an existing WS into the back-end subsystem of the proposed framework so that it adheres to the ontological definitions of services. This process is performed by any SP who is interested to provide one or more services that deliver content in the one of the application domains and for those user groups that are defined in the context of the proposed project. Service alignment is facilitated by the SAT, which is equipped with a web-based user-friendly interface, shown

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in Figure 3. The aforementioned process results into the completion of service integration whose purpose is to enable the efficient invocation of services whenever it is requested by any of the integrated client applications.

➢ *Service Integration*

SPs participate in the service alignment process by being able to establish relationships between the services and the ontologies. WSs are described in the service ontology by the service model that defines the operations and the structure that should characterize any registered WS.

Before the alignment takes place, SAT collects information about the SPs. Any registered provider has the ability to navigate through the supported models as these are defined in the service ontology. SPs correlate their WSs with the ontologies. By doing so, WSs are consistently marked up. The alignment mechanism facilitates a flexible standardization process.

In this context, 'similarity' between the ontology and the WS is established when the following criteria are satisfied:

- the inputs of the supported WS operations are identical to the inputs provided by the service model's operations
- the outputs of the real WS operations are described by the outputs provided by the service model in the ontology.

Fig 6 A snapshot of the SAT user interface

Notes: SPs may exploit drag-and-drop functionality in order to provide mappings of data types and operations defined in their services to the corresponding fields.

The SAT allows any SP to see the ontological operations that are defined in similar manner to those appearing in a WSDL file. Furthermore, by clicking on the operation models, SPs can get information about the inputs and outputs that their services must have in order to comply with the model.

After the identification of the appropriate model, the providers should select from a drop-down list the operation that complies with the service they want to register. Thus, they provide the uniform resource identifier (URI) of the WSDL file that describes the service. At this point, the tool automatically parses the WSDL file and extracts the required information. In this context, any service can be described by the triplet:

$S =< P\_id, wsdl, op[\ ] >,$

where *P_id* is the provider's identifier, *wsdl* is the URI to the WSDL service description and, *op* is a list of defined operations. Each operation is defined as:

$op =< name\ i, ,_1 \ldots, i_n, o >,$

where *name* is the name of the operation, $i_1, \ldots, i_n$ its inputs and *o* its output.

Let us assume that service *S* is described in the ontology by the service ontological representation S_m. Two arbitrary operations $op \in S$ and $op_m \in S_m$ have a degree of similarity equal to 1, when they have equal number of inputs and also: $i_k \equiv im_k$ and $o \equiv om$, $\forall i_k, o \in op$ and $im_k, om \in op_m$, where $k = 1 \ldots n$.

The alignment process, which is performed by the provider initially determines the degree of similarity between the operation defined in the ontology and the one that has been selected to be included as part of a registered service. It is up to the SP to verify the accuracy of the alignment operation and select the service to be aligned.

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The last step of the service alignment procedure involves mapping of inputs and outputs between the service to be aligned and the proposed framework ontological service model. This process, which is supported by drag and drop operations on the GUI is illustrated in the snapshot of Figure 6. Once this final step is completed, the information of the alignment operation is stored in a registry of services, known as service repository. In this way, the invocation of services is enabled through the back-end system. The invocation mechanism handles incoming requests for specific content by the client applications and launches the appropriate services in order to receive the required content.

➢ *Service Invocation*

As soon as a service alignment process is completed, the newly aligned service is integrated within the system's back-end and at the same time a new entry is added in the service repository. Actual service integration involves manual generation and compilation of the required source code of the wrapper that corresponds to the newly aligned service. This wrapper provides the necessary mappings and transformations between SP's native data type formats and the proposed framework ontological description of data types and services.

After the completion of the alignment process, the invocation of the real WSs is then performed based on SOAP. Each WS is described by a WSDL file, which contains a complete description of the WS that facilitates the invocation process.

This software, often referred to as the WS client stub is a WS client. Thus, in order for the DMM to be able to access a WS, it should have the client stub code of the integrated service, which provides the ability to call the service each time this is requested by the user interface.

➢ *Usage Scenarios*

In the framework, a wide range of services have been defined with respect to the following domains:

- ✓ transportation
- ✓ tourism and leisure
- ✓ personal support services
- ✓ work, business and education
- ✓ home automation
- ✓ social relations and community building.

All content, required for the implementation of the various use cases, becomes available through a set of WSs. The required content is being rendered on the user device, each time a user sends a request via the user interface for a particular type of content. It should be noted that the whole process of service search, selection and invocation is executed in a seamless way on behalf of the users. For example, a user who is interested in finding information about the available restaurants that are located within a specific range activates the search for points of interest (POI) application performing the following actions:

- ➢ selects the restaurant POI type from a drop-down list
- ➢ specifies the range (e.g., 1 km)
- ➢ provides accessibility preferences of the POIs to be returned (optional)
- ➢ presses a 'search' button on the user interface.

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Fig 7 Snapshots of the system' PDA end-user application

The user interface then sends a request for a list of POIs to the DMM. A service search and retrieval mechanism submit a semantic query to the ontology requesting a list of POI search services. Among the returned services, the one that is ranked first according to a set of quality of service (QoS) criteria is selected for invocation and then a message is sent to the DMM. In practice, this is performed by a filtering mechanism that ranks the returned results according to the user's previous choices. After this step, the appropriate wrapper is activated whose responsibility is to transform user input into the particular WS-specific format. The wrapper finally invokes the service providing the right values for its parameters.

- The main QoS criteria that are taken into account for the invocation of services include:

* The frequency of use of the particular service, i.e., how many times the user has requested invocation of this service.
* The geographical location of the service. This is especially necessary in order to make sure that the selected service will provide localized or location-specific information, which is required in a mobile and ubiquitous environment.

In the most common use cases, users request the availability of general-purpose location-aware, localisation, guidance and travel assisting services.

Figure 7 above shows a number of such use cases, assuming that the user is equipped with a Java-enabled PDA device with an integrated GPS sensor. All these use cases involve user requests for content that is available via a set of registered WSs. For each user request for content, a corresponding WS is invoked that has been aligned on the grid.

All screenshots of the main application shown in Figure 7 are displayed on a device running Java J9 version 1.4 under Windows Mobile version 6.0. The following use cases and the corresponding end-user services are displayed.

- *Indoor User Localisation:-*

Users send through the user interface a request for a localisation service. This service actually returns a map that shows the user's current location. When a user is located inside a building, an appropriate network of indoor location-aware sensors (e.g., Zigbee devices) is required in order for the service to be able to locate the user position. In this case, an indoor map is displayed by the invocation of the appropriate WS.

- *Outdoor Localisation:-*

The localisation operation supports seamless transition between indoor and outdoor maps. Once the user leaves an indoor area, the map that displays the current user position automatically ('seamlessly') changes to an outdoor map. In outdoor mode, the user position is received via the GPS sensor. The opposite action is also supported, i.e., when the user goes from outdoors to indoors, the map changes back to an indoor map.

- *Search For Pois:-*

This facility allows the user to search for POIs of specific type (e.g., museums, restaurants, etc.). Information about the requested POIs is based on the user profile and specific type of impairment. After the user receives a list of available points of interest, route guidance capability is enabled, as an integrated facility, in order to guide users to the place chosen from the list of POIs.

- *Indoor Route Guidance*:-

Route guidance is also available as a stand-alone service, activated on demand. Users may explicitly request to be guided to any POI via accessible routes, starting form an indoor location.

- *Outdoor Route Guidance*:-

The route guidance service is offered for both indoor and outdoor locations. The invocation of this service results in a route drawn on a map that the user should follow in order to reach the requested destination. As the user moves from an indoor place to an outdoor area, the map changes accordingly.

- *Search For Social Events*:-

The user is able to request a list of social events that may occur nearby. As soon as the users select a specific social event and express their interest in this event, the route guidance service is invoked in order to show them how to move to the place of interest.

- *Distance Learning*:-

The proposed system distance learning functionality contains a set of services and tools to facilitate courses taken on a long-distance basis.

- *Distance Working*:-

Supports e-working capabilities (e-mail, calendar, document authoring), which are enable by the invocation of the corresponding WS.

IV. PERFORMANCE EVALUATION

These following set of metrics captures various aspects of performance and scalability evaluation of semantic web databases. During the proposed framework's evaluation, these two important parameters were considered, i.e., *execution time* and *resource usage* for execution cost of a test case. Based on test cases, we considered *main memory*, *CPU time* and/or *secondary disk space* as cost primitives for *resource usage* to build an in-depth study of performance.

- *Load Time*

This metric gives loading time *T* for datasets of different sizes. Load time is measured as a cumulative time to build a repository structure, build initial index structures and generate statistics about a dataset for query optimization.

*T*Load = *T*RepositoryCreation + *T*LoadDataset + *T*IndexCreation
+ *T*StatisticsGeneration

- *Query Response Time*

This metric provides query execution time *T* for each test carried on datasets of different sizes. Query execution time includes time to connect to a repository, execute the query, print its result set and then close the connection.

*T*Execution = *T*OpenConnection + *T*ExecuteQuery + *T*PrintResultSet
+*T*CloseConnection

➢ *Main Memory*

This metric compute memory required for execution of a particular test case. This is the amount of memory needed to hold working buffers. Small size of main memory is a limit on size of the semantic data that can reside or process in main memory. For our analysis, we have considered the maximum committed memory for a task as memory used to measure each task.

➢ *Cpu Time*

This metric shows CPU time consumed for processing a particular test case. Whenever a test case is executed by a user, it engages some of system resources among which CPU time is important, because the higher the percentage of a CPU used by a semantic store, the lesser the power the CPU can devote to other tasks.

Table1 Semantic Web Databases and Datasets Success Ratio

Entries	**Datasets**								$\mathbf{SR}^{\mathbf{Entries}}$
	1		**2**		**3**		**4**		
	S	F	S	F	S	F	S	F	
First Usage	7	0	7	0	7	0	0	7	0.75
Second Usage	7	0	7	0	6	1	0	7	0.71
Third Usage	7	0	7	0	6	1	4	3	0.86
Fourth Usage	7	0	7	0	6	1	5	2	0.89
Fifth Usage	7	0	7	0	7	0	5	2	0.93
Sixth Usage	7	0	7	0	6	1	5	2	0.89
Seven Usage	7	0	7	0	6	1	5	2	0.89
SRDatasets	1.0		1.0		0.89		0.49		

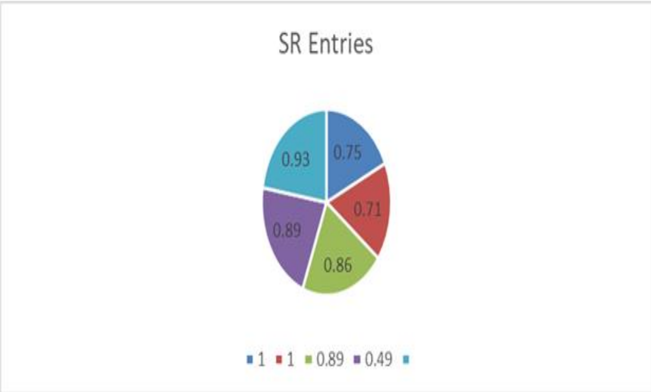

Fig 8 SR Entries

➢ *Repository Size*

This metric presents storage size *S* occupied by a dataset after loading it into persistent storage. Repository size is a composite figure of the total size of all files present in the repository, including data files and index files.

*S*Repository = *S*DataFiles + *S*IndexFiles

➢ *Success Ratio*

Success ratio describes the fraction of successfully executed test cases either for a semantic store or for a dataset. For success ratio computation, we considered one bulk load test case and six read test cases (i.e., a total of 7 test cases on a dataset) to develop a better effect of failed tests. For each store and dataset size, the success ratio is calculated using the formulas given in Equation. 1 and 2, respectively.

*i*4=1 STstoredataset(*i*)
SRstore = *i*4=1 store
TTdataset(*i*)
7 STdataset
SRdataset = *i*7*i*=11 store/

TTstoredatasetstore((*ii*))

where $SR_{entries}$ and $SR_{dataset}$ are success ratio for entries and dataset, respectively, $ST^{entries}_{dataset(i)}$ represents a number of successful test on dataset *i* for entries, $TT^{entries}_{dataset(i)}$ shows a number of total tests on dataset *i* for entries, $ST^{dataset}_{entries}(i)$ represents a number of successful tests on store *i* for dataset and $TT^{dataset}_{entries}(i)$ represents a number of total tests on entries *i* for dataset.

V. CONCLUSION

The results of the survey revealed that the blind individuals have tough times accessing and navigating web apps. It is commendable that developers do their best to incorporate all necessary tools and approaches into semantic web application as technologies evolve on daily basis.

Also, the developed semantics web framework should be employed for use by the blind students due to its consistency as well as processing power and computation speed.

➢ The suggestions for further studies are as follows:

- Further research can be carried out using the hybridization of ensemble learning and deep learning.
- Further research could deploy the framework into a system for commercialization.

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