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Cochlear Implantation Domain Knowledge Representation and Recommendation

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Abstract

Cochlear implant is an assistive device for hearing impaired. Its surgical procedure involves serious of decision to be made by the clinicians, parents and patients. Demands on the early diagnosis of hearing impairment are much required to augment the hearing disability. Cochlear implantation decisions plays vital role, in the development of speech, and cognition in case of children. This poses a greater importance on the knowledge representation. Medical knowledge on cochlear implant should be semantically coded for its usage in hospital working on different platform. The medical Ontology is the most powerful tool to encode these medical facts semantically. This research work mainly aims in building an ontology to code this medical knowledge and build a decision support system to predict the cochlear implantation outcome. The ontology is built using web ontology language (OWL) and OWL pellet reasoner are utilized to reason the knowledge represented.

Keywords: ontology ,reasoner,cochlear implantion , decision making system.

I.INTRODUCTION

Diagnosing a patient for a disease involves complex decision making procedures and it is very much critical, since it involves the betterment human life. The decision also should be very specific and patient centric. Development in the field of artificial intelligence, machine learning, deep learning, more algorithms for taking complex decision is coined. These facilitates the decisions taken by the clinicians and help the health care professionals.The quality of care given to the patient, patient safety ,the accuracy and the effectiveness are also improved .This research mainly aims in developing a recommendation system in the field of cochlear implantation .

Clinical decision making system is an automated system which proves its efficiency in clinical decision. It is also designed to improve clinical decisions-making. New patient centric information are generated by using the represented knowledge, the algorithm and with the different set of inputs The coded computerized knowledge base along with software algorithms, and the input patient data generates the of recommendations specific to patients.CDSS are developed for prohibiting the adverse effects created by human errors and thus reducing the cost of treatment and improves patient care provided.

The knowledge base and inference engine collabrately with the most relevant modules of CDSS enhances the reasoning abilities. The conclusion on the recommendation or clinical diagnosis is obtained by analyzing the patient symptoms and cross validating the rules in the

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knowledge base

The ability of a human to distinguish the sound received is known as perception of sound. Hearing loss is the inability to recognise the sound which can be unilateral or bilateral. In children hearing problems can affects not only perception of sound but also the speech and language development and his cognitive skills. In the working environment, hearing disabled persons faces psychological problems in view of the fact that they are bullied. In elderly old people this defect creates loneliness. To augment this difficulty the person goes in for hearing aid, surgical implantation of cochlear device or use sign language. Hearing aids helps the disabled by strengthening the sound received and delivering the same to the ear. This assists them to perceive the sound around them. If the inner ear is too damaged, the amplified vibrations won't be converted into neural signals, making a hearing aid obsolete. Hence they go in for a Cochlear implantation. Cochlear implant is an electronic devices, which is a surgically implanted to transduce the sound or the mechanical vibration into electrical signals. These electrical signals are sent the brain for further decoding. The cochlear implantation may benefit the profoundly deaf or severely hard of hearing in both ears. CDSS for cochlear implantation is thus very much necessary for its importance in deciding to go in for implantation surgery.

2.RELATED WORKS

A rule ranking base system is designed as a domain ontology for acute kidney disease.Here post analysis based concept are employed to identify and suggest the recommendations based on the frequent pattern that occur .(S.Antoinette Aroul Jeyanthi 2017).The unimportant rules are discarded by using filtering techniques.Ranks for the rules are assigned after filtering .based on the ranked rules and and risk factor the prediction of the disease is being done .

To make the system semantically interoperable the electronic medical record should be semantically encoded as semantic resources .In an ontology based model for diabetic patient , the electronic medical record has been build semantically by using a domain ontology . (Li Chen 2019) Efficient decision are taken by applying the rules in semantic web rule language.

Ontologies are also used in making decision related to pregnancies .An ontology is constructed in involuntarily of high risk pregnant woman. Here an online datases of pregnant woman is utilized .Its a two step process in which the Rules extractor extract the rules from the above dataset by means of WEKA and Rules to Ontology Mapper is liable to construct ontology from the extracted rules by WEKA(Umar Manzoor 2014).

Ontologies are also used in developing domain knowledge in the software fields also.SRMONTO has six stage including enumerating the issues related to software risk domain ,developing the subontology for software risk,merging those subontology created ,the environmental implementation, inspect the application of the environment(Rene Robin 2010)

Ontologies find its application in websearch engine .Personalized approach is much required which can be achieved by using ontologies .Ranking is done by a machine learning approach namely Support vector machine (R.Diviya 2014)

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Phan et al used ontologies for predictintg the human behaviour using the domain knowledge and have also deduced the reason the behaviour(Phan 2017)

3.PROBLEM STATEMENT

Hearing is the sense of sound and listening is attendings to the auditory stimulus. Listening can be the thought by giving a meaningful sound. This provides the brain to organize for establishing vocabulary, develop receptive and expressive language skills and learn more internalize concepts. Hearing is essential for normal speech and language development, communication and learning. Hearing loss refers to a decrease in the ability of person's sensitivity to sound, or diminished ability to hear sound like others. Lack of hearing cause a significant delay in the child's speech and language development. It leads to poor vocabulary development, difficulty in grasping new subjects, and learning problems, which results in poor academic performance of the child. Hence right decision is to be taken to in case of cochlear implantation surgery. An effective CDSS system is highly required to reduce the error and omission in take clinical decision in cochlear domain .The knowledge should be shareable and platform independent .the knowledge developed should be made expandable for its growth .Ontology is the only choice of design for the objective chosen.

4.METHODOLOGY

To design a Decision making support system for Cochlear Implantation using Ontology web ontology language is used .The ontology is used to represent the cochlear implantation knowledge in the form of classes, individuals .relationship between the classes in the form of Object properties ,and the data properties are build.Fig 1. depicts the overall architecture of the research work

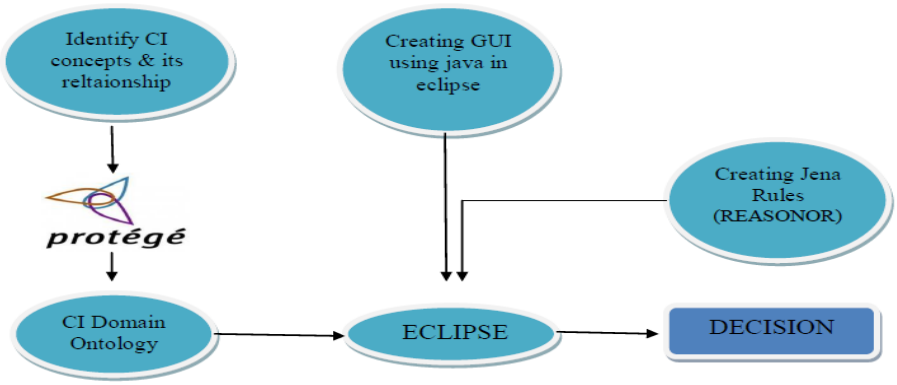

Figure 1: Workflow for CDSS

4.1 BUILDING CI ONTOLOGY IN PROTÉGÉ

Ontology is a methodology which provides systematic, semantic links among a collection of related concepts. It is a formal explicit specification of a shared conceptualization. Domain ontology is a form of concepts, Individuals belonging to these concepts and relationships between the concepts and relationship between concepts and individuals.

The various concepts in cochlear implantation domain were being identified and its relationship and properties were established.CI ontology is being built using the protégé software tool in OWL (Web Ontology Language).The general steps to create an ontology for CI is to identify the concepts related to cochlear implantation domain. Contemplate to reuse the existing ontology in the cochlear domain .identify the concepts of cochlear domain and arrange the concepts and identify them in the form of hierarchal relationship between the concepts identified.

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Establish the relationship between the concepts in the form object properties .Data properties establish the relationship between a class and datatype values prescribed by the language .

4.2. BUILDING CLASSES OF CI DOMAIN

Some of the important criteria for cochlear implantation are identified and coded as criteria for Cochlear Implantation knowledge .Some of the important concepts of the cochlear domain are discussed in this session. Tympanometry, a clinical procedure which aims in diagnosing hearing disorders. The movement of the tympanic membrane for changes in the sound pressure are measured and plotted in tympanogram

Auditory brain stem function is analyzed by the auditory brainstem response (ABR) It is a neurologic response when auditory stimulus is given. An acoustic transducer present in the head phone is utilized. A click or tone in brief is generated. The evoked potential for this sound or click is being recorded. These signals are picked up by the body surface electrodes placed on the scalp and at the reference the ear lobe. The waveform peaks are labelled I-VII.This test mainly aims in determining the status of the organ namely the cochlea, the hair cell function By analyzing the waveforms of ABR it is possible to screen the neonates and infants for hearing disability. Figure 2 depicts some of the important concepts identified in the cochlear domain.

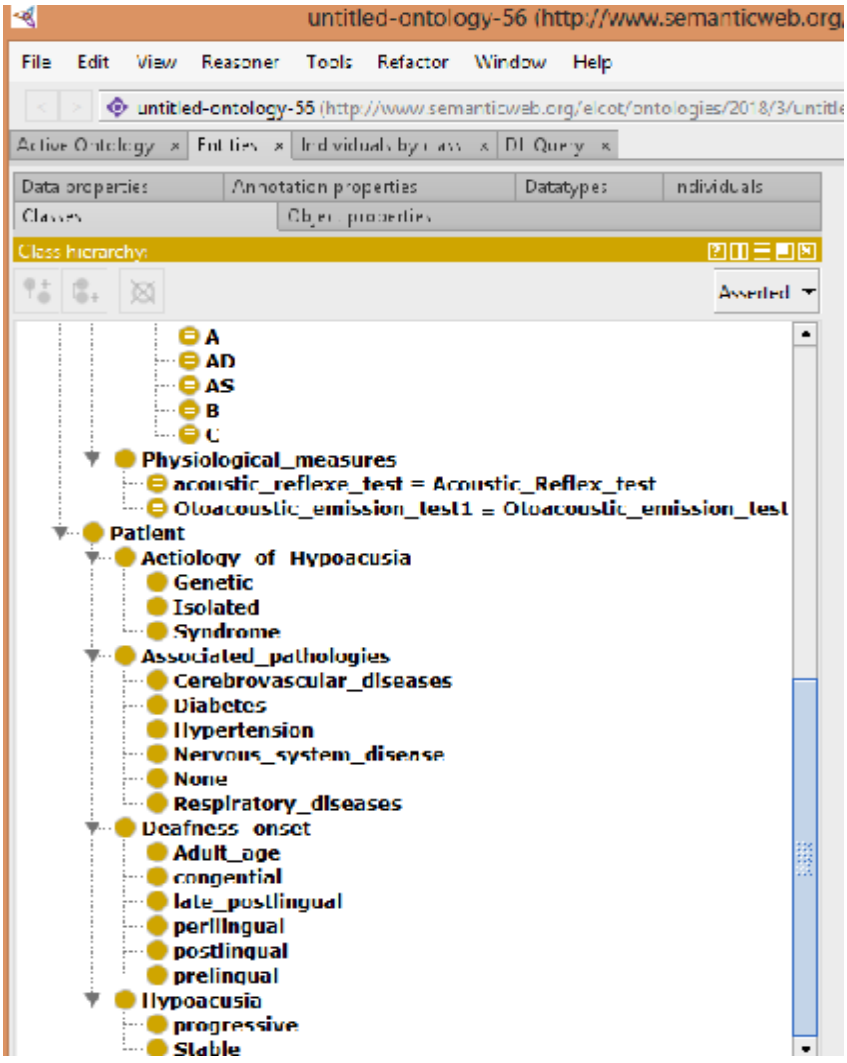

Figure 2.classes of cochlear implanatation domain

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4.3 CLASS PROPERTIES DEFINITION RELATED TO COCHLEAR DOMAIN

The two properties need to build to define the relationships that exist in the ontology. They are object type property and data type property. An Object property is the property which define the relationship between the two classes.Some the important Has_asociated_pathologies ,Has_aetiology_of_hypoacusia,Has_hypoacusia. Has_test , Is_a_behavioural_measures,Is_a_component_of. Facets is also known as Data property.The Data property defines the relationship between the domain the class and the range is data value .Some of the important data property are Has_age,Onset_of_deafness_at_age_of, Has_HINT_score, Has_CNC_score, Has_AR_range_of, Has_gender, Has_OAE_range, Has_lower_bound_range,Has_upper_bound_range

4.4 CREATING INSTANCES OF THE CLASS.

The individual or instances of the class can be defined in web ontology language .The properties and the value associated can also be coded. This makes the individual to extensively expressed. To create individuals in Protégé the 'Individuals Tab' is used. The patient id is automatically generated and the names of the patient are stored. Their test results are coded as Datatypeproperty values. Fig 3.shows the Datatypeproperty that are created

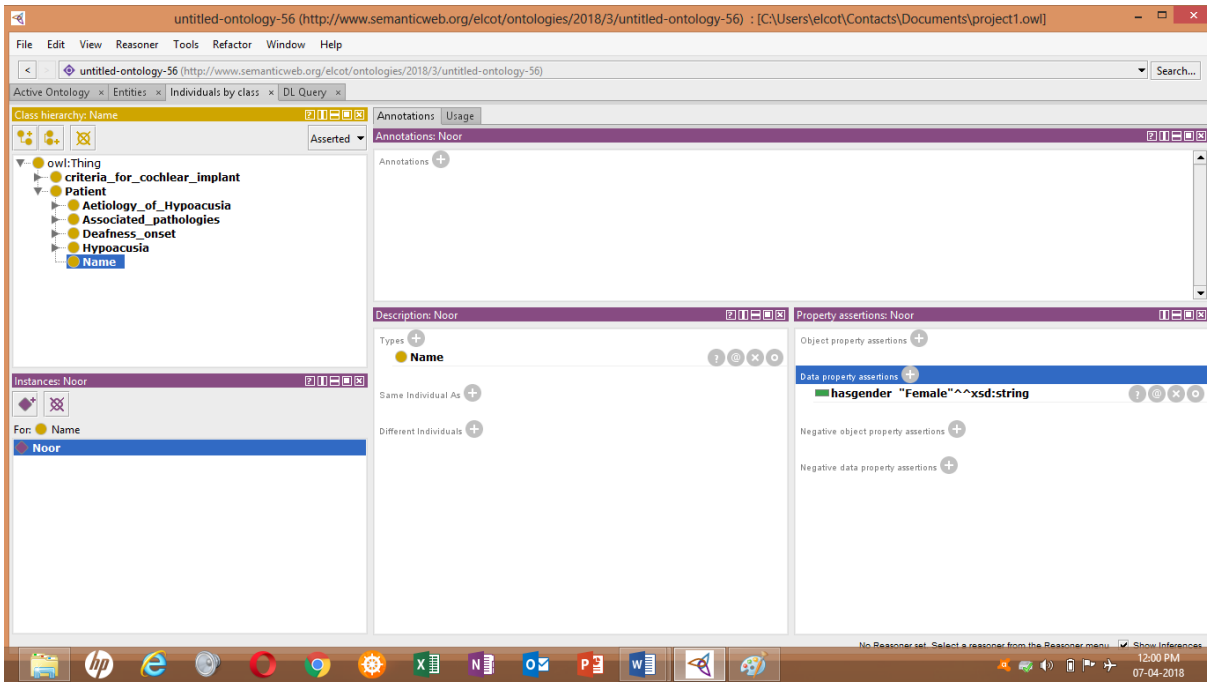

Figure 3.datatype property of cochlear implanatation domain

Ontograph model is a graphical representation of the ontology we have created. It helps us to easily understand what are the classes represented, relationship between the classes and relationship between the class and the individuals. The relationships in the ontology can be viewed and interactively communicated by using the Ontograph.The hierarchical relationship are also maintained in this view. Figure 4 shows the owl wizard a visualization tool for ontology.

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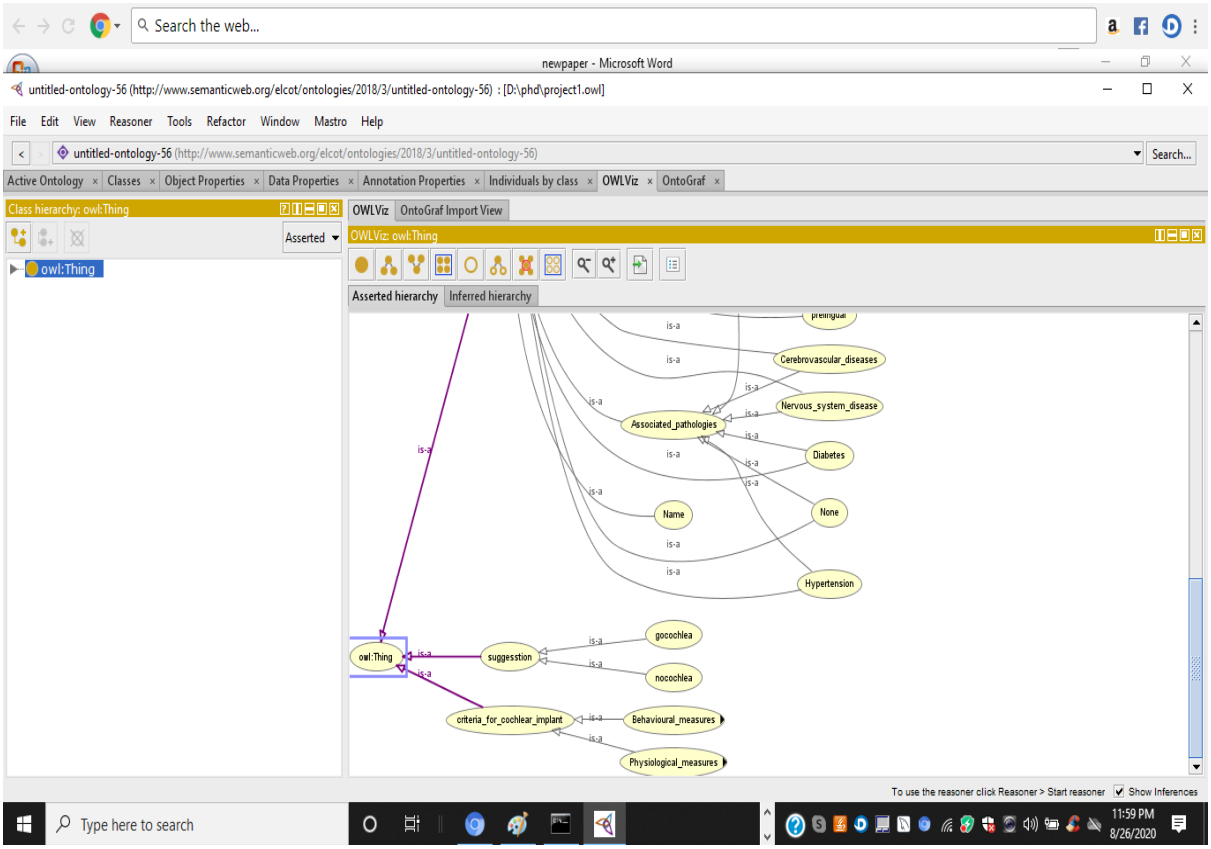

Figure 4.owl viz for Ci domain

4.5 SEMANTIC WEB RULE LANGUAGE (SWRL)

SWRL consists of a set of atoms which are implicitly connected by conjunction.SWRL mainly is used to come out of the limitations posed by the OWL language in expressing the relation. This being done by combining the OWL-DL and OWL Lite .This rule language consists of two parts .it is mainly based on the antecedents and consequent basis . The antecedents are combined by using conjunction .These rules in ontology is coded by using SWRL Tab of the protégé software.Pellet reasoner is used to deduce or infer the new facts from the ontology depending on the rule specified by the SWRL.The table 1 shows the rules that is being developed to strengthen the knowledge created.

Rule no	Swrl Rule	Explanation
1	Patient(x),has age(?x,?y),lesserthan(?y,12),hasbilateraldeafness (?x,?z),haspuretoneaverage(?x,?avg),hasDBHL(?x,?val),greaterthan(?val,70) →hasbenefit(?x,no)	Children older than 12months undergone a bilateral deafness with the pure tone average of greaeter than 70 will have no benefit from hearing aid
2.	Patient(?x),hasmlnt(?x,?score),withinrange(?score,20,30)→hasbenefit (x)	A person undergone multisyllabic lexical neighbourhood test and has score between the range 20 and 30 will have benefit form hearing aid
3.	Patient (x), hasitmais(x,score), greaterthan(?score,40)→benefit (x)	A person has undergone infant toddle meaningful auditory integration scale has got in the score greater than 40 then he is going to be benefitted by hearing aid

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4	Patient(x)patternperception(x,type),stringequalignorecase(type,?object),hasWIPItest(?object,?s),lessthanequal(?s,30)→hasconcern(?x,no)	A person undergone a test for speech perception test to identify an object and the score is less than 30 then he has no concern in going in cochlear implantation
5.	Patient(x), hasdod(?x,?y), lesserthan(?y,4)→ hasconcern(?x,no)	A person having duration of deafness less than 4 of age then he has no concern in going for implanation
6.	Patient(x), hasdod(?x,?y),withinrange(?y,4,6)→ hasconcern(?x,mildconcern)	If the person having duration of deafness in the range of 4 to 6 years have mild concern when going for implantation
7.	Patient(x), hasdod(?x,?y),greaterthan (?y,4,6)→ hasconcern(?x,greatconcern)	A person having duration of deafness less than 4 of age then he has no concern in going for implantation
8.	Patient(x),hasdod(?x,?y)greaterthan(?y,4) →hasplasticity(?x,high)	Neuronal plasticity is high if the deafness fduration is greater than 4
9	Person(?x),hasplasticity(?x,high)→hasconcern(?x,greatconcern)	If the person has high neuronal plasticity high then his benefit out of the cochlear implantation is less.
10.	Patient(x),hasotolaryngological (?x,?y) , hasvalue(?y,?z), stringequalignorecase(?z,good)→ hasconcern(?x,noconcern)	If the person has good otolaryngological aspects then has no concern in going with cochlear implantation .
11.	Patient(x),hasotolaryngological (?x,?y) , hasvalue(?y,?z), stringequalignorecase(?z,airwaydisorder)→ hasconcern(?x,mildconcern)	If the person has airway disorder then he has mild concern in going with implanation
12.	Patient(x),hasctscan(?x,?y),hasdiamalformation (?x,?cochlea,stringignorecase(?cochlea,normal) →hasconcern(?x,noconcern)	If a person diagnosed with no malformation of cochlea in ctscan can benefit from this cochlear implantation
13.	Patient(x),hasctscan(?x,?y),hasdiamalformation (?x,?cochlea,stringignorecase(?cochlea,ossified) →hasconcern(?x,mildconcern)	If a person diagnosed with ossified of cochlea in ctscan can benefit from this cochlear implantation
14.	Patient(x),hashandicaps(?x,?y),stringignorecase(?y,no)->hasconcern(?x,no)	Cochlear implantee will benefit if he does not have any other handicapped
15.	Patient(x),hasusageofHA(?x,?y),hasusage(?y, ?z),lesserthan(?z,0)→ hasconcern(?x,noconcern)	If the person have not used the hearing aid at all he benfits of cochlear implanation

Table 1:Rules of SWRL in cochlear Implantation domain.

These rules are executed by using pellet reasoner and new inferences are created .Pellet reasoned is standard plugin for the protégé software . Using the above methods and rules, the Clinical Decision Support System (CDSS) for the Cochlear Implantation (CI) is created. It helps the physician to easily predict whether the CI is Compatible to the patient or not. It also avoids the Cross modal plasticity.Figure 5 shows the reasoning done with the drools reasoner.

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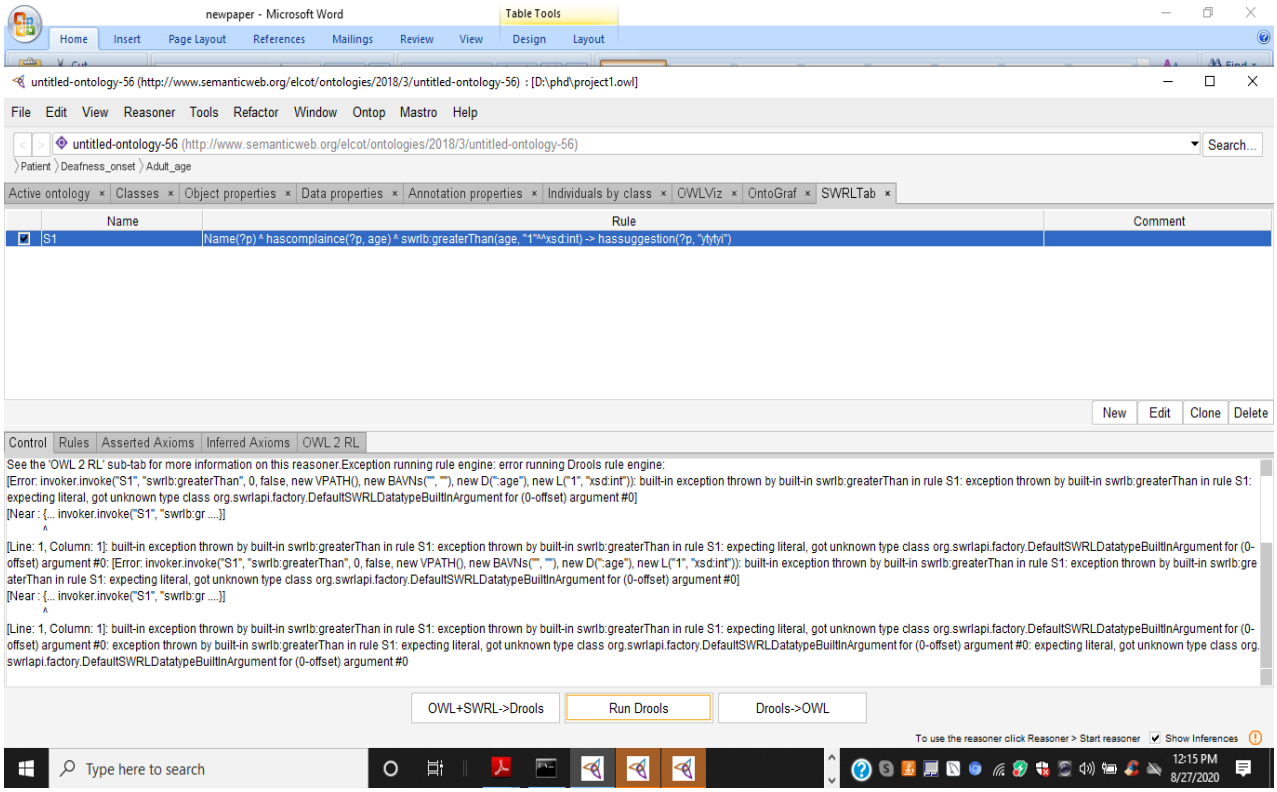

Figure 5.Resoning in cochlear implanatation domain

Figure shows the rule reasoned and swrl tab in which the rules are encoded.
The properties ,classess, and instances can be queried by using sparql query .An example sparql query for reterivieng the dataproperty is

```
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>

SELECT ?dtyppe (STR(?z) AS ?label) WHERE {
        ?dtyppe  rdf:type owl:DatatypeProperty .
        OPTIONAL {?dtyppe rdfs:label ?z}
}
ORDER BY ? z
```

This query retrieves all the data property.

5.EVALUATION RESULT:

The developed system for its evaluation was run with real time dataset acquired from the leading hospital in Chennai .The patient is entered as individuals in the ontology and the test values are coded as datatype property .For easy use of the System a GUI was developed and the patient data is keyed in and the ontology is update through the java programming environment. Clinical Practice Guidelines for Cochlear Implantation, Clinical Guidelines for Paediatric Cochlear Implantation is also used for the domain representation. The inferred suggestion of the ontology is compared with the actual suggestion from the domain experts the clinicians. The CI recommendation is analysed by using the following evaluating performance measure namely

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Accuracy, specificity, sensitivity, false positive rate, false negative rate.
220 patient data was analyzed .These patient were grouped into two. Out of which 130 are adult with the age greater than 18 .Other are the children and adolescent .The confusion matrix is obtained for each age group Figure 6a,6b,6c shows the confusion matrix.

Actual values	Recommended values	
	53 (TP)	57 (FP)
	32 (FN)	78 (TN)

Figure 6a. Confusion matrix for the total data set

Actual values	Recommended values	
	45 (TP)	20 (FP)
	31 (FN)	34 (TN)

Figure 6b. Confusion matrix for the adult group

Actual values	Recommended values	
	21 (TP)	24 (FP)
	22 (FN)	23 (TN)

Figure 6c. Confusion matrix for the children group

$$\text{Accuracy} = TP + TN/(TP + FN + TN + FP) \times 100 \quad \text{.....} \quad (1)$$

$$\text{Sensitivity} = TP/(TP + FN) \times 100\% \quad \text{.....} \quad (2)$$

$$\text{Specificity} = TN/(TN + FP) \times 100\% \quad \text{.....} \quad (3)$$

$$\text{Precision} = TP/(TP + FP) \times 100\% \quad \text{.....} \quad (4)$$

$$FPR = 1 - \text{Spec}; \quad \text{.....} \quad (5)$$

$$FNR = FN / (TP + FN); \quad \text{.....} \quad (6)$$

Figure 7 depicts the evaluation metrics for Accuracy, Precision , ,Sensitivity, Specificity . The accuracy is more for adults when compared to the children .Many underlying factors for children have to be taken care in case of children . It is inferred from the graph that not only the accuracy,but sensitivity , specificity and precision also less when compared to the children and adult .because of this the accuracy of the combined group also decreases.

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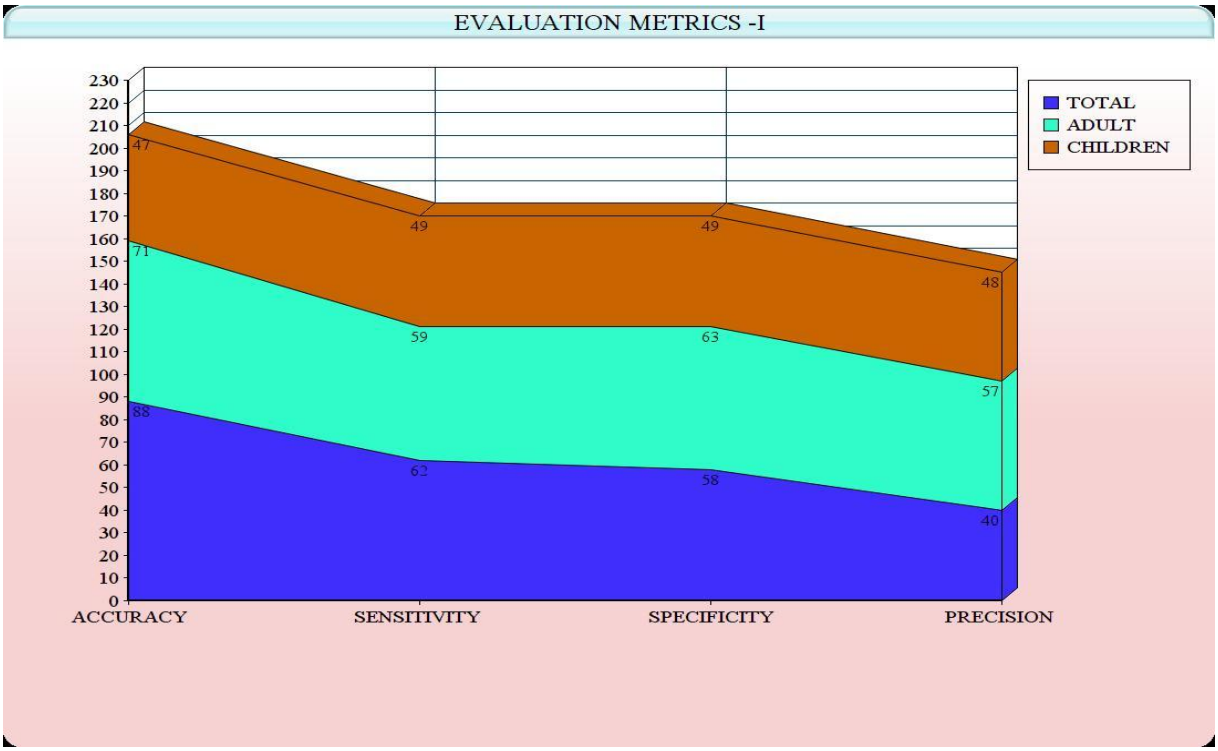

Figure 7 . Evaluation Metrics- I(Accuracy,Sensitivity,Specificity,Precision)

The figure 8 clearly depicts there is positive predictive value for adults .But the false positive rate and false negative rate for the group 2 the children is high indicating that the recommendation for children should be improved for pulling up the total performance.

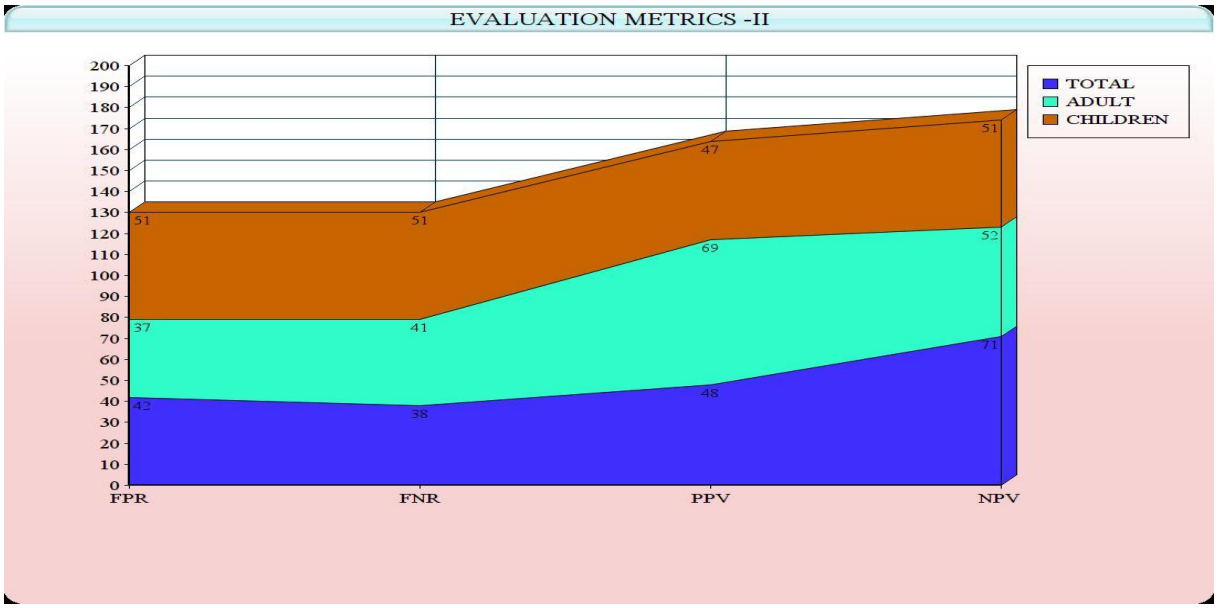

Figure 8 . Evaluation Metrics- I (False positive Rate,False negative,positive predictive value ,negative predictive value)

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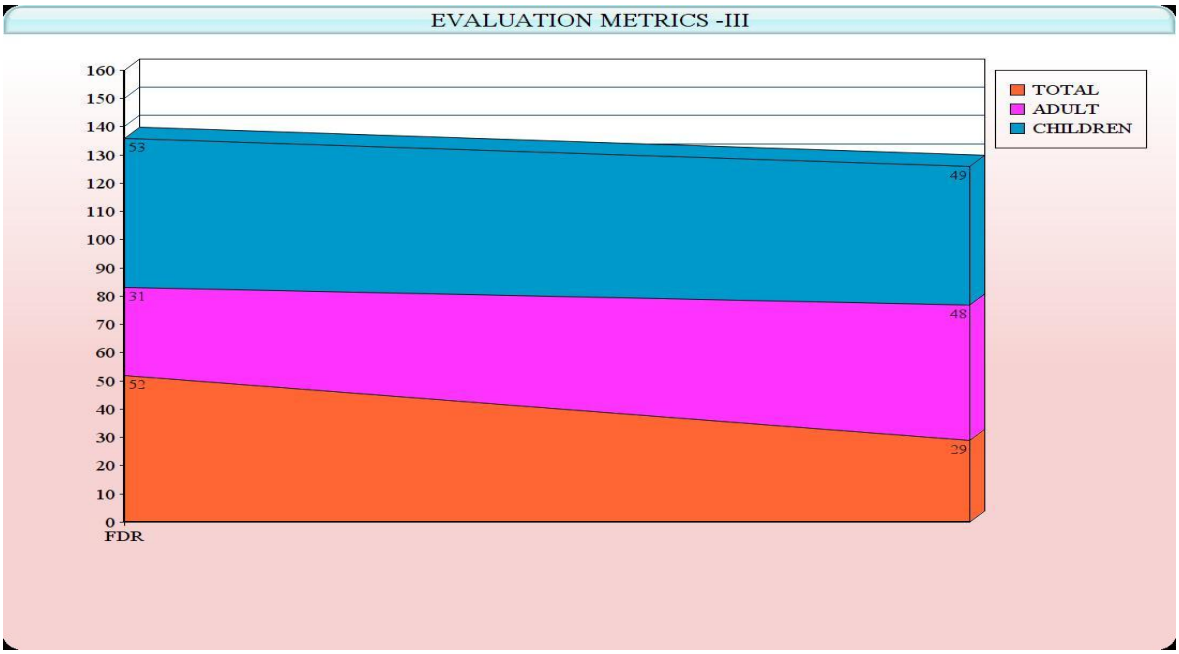

Figure 9 . Evaluation Metrics- III (False Discovery Rate,False Omission Rate)

6. CONCLUSION AND FUTURE WORK

Ontology is most powerful and commanding tool for generating the medical knowledge semantically. The medical knowledge thus represented are platform independent and can also be utilized for further enhancement and reuse .The knowledge for cochlear implantation domain was developed using web ontology language and enhancement of the same for its expressivity by exploiting semantic web rule language .The ontology created was able to give useful recommendation for adult than for children as studied by the use case. Thus the cochlear implantation decision for children is different than the adult criteria.The concepts of criteria for children implanation of cochlea and its association rule can be incorporated in detail for the future work.

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