International Journal of Intelligent Information Systems
2021; 10(6): 109-116
http://www.sciencepublishinggroup.com/j/ijiis
doi: 10.11648/j.ijiis.20211006.11
ISSN: 2328-7675 (Print); ISSN: 2328-7683 (Online)

Ontology Based Recommender System for Diabetic Patients

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To cite this article:
Simachew Melaku, Melkamu Beyene. Ontology Based Recommender System for Diabetic Patients. *International Journal of Intelligent Information Systems*. Vol. 10, No. 6, 2021, pp. 109-116. doi: 10.11648/j.ijiis.20211006.11

Received: September 29, 2021; **Accepted**: October 28, 2021; **Published**: November 17, 2021

Abstract: Chronic diseases are a persistent and long-lasting human health conditions that lasts for more than three months. Today the prevalence of chronic non-communicable diseases in Ethiopia increases rapidly because of different reasons like poor nutrition habit, lack of physical activities, drinking alcohols, smoking and life style issues. To overcome this problem different technological applications are developed globally to support both the health professional in diagnosis process and the patients for their self-treatment activities. Ontology helps to create common understanding between human and computers, enable reusability of information, and allows sharing of concepts. Ontology based personalized recommendation model is for diabetic patient in Ethiopian context. We have used design science research methodology in our proposed study. In the development of the proposed model, first we have developed the patient and domain or disease ontology and then the two ontologies needs to integrate in order to develop the required recommendation model. We have used Protégé ontology development tool for the development of the proposed domain or disease and patient ontology. This research discusses how to develop patient and domain or disease ontology and then it also describes how two ontologies need to integrate in order to develop the required recommendation model.

Keywords: Chronic Non-communicable Diseases, Information Retrieval, Ontology, Recommendation Model

1. Introduction

Chronic diseases are complex issues and require repeated collaboration and contact between patients and health care providers. It is the leading cause of death, killing more people than all other disease in each year. At this time, Low and middle-income countries are highly affected by the problem with chronic disease as compared with developed countries. Large amount of social, health and economic losses have occurred because of the high prevalence of chronic disease. Around 80% of death in Ethiopia is caused by those chronic NCD [4]. In Ethiopia health care system is not designed well for chronic disease. This adds to the nation's burden of poverty, slow down development and increase health inequities, which are believed to impose a huge demand on the healthcare system, creating economic pressure in the country. Today large number of people lives with serious chronic disease. These chronic disease leads to a serious effect unless permanent treatment is performed both by health professionals and the patient themselves. This may be related to other factors resulted from poor quality of life. Behaviors that increase the risk of chronic disease includes unhealthy diet, physical inactive, obesity, alcohol drinking and tobacco use and others [1]. According to world health organization's report in 2011 around 34% of Ethiopian people died with chronic non-communicable disease, among which 15% is because of cardiovascular disease, 4% is because of pulmonary disease, 2% is because of diabetes mellitus and others [9]. In 2013, the death impact of communicable disease reached around 73.7% [10]. Because of this high prevalence of non-communicable disease in Ethiopia, it is important to have some additional technology to help patients and health professional in the treatment and diagnosis process of common chronic diseases.

Different applications have developed today that helps to treat and diagnose patients with remote service. The current working solution primarily focused on intensive prevention and diagnosis at hospitals rather than on continuous and personalized chronic disease management outside healthcare centers [11]. Current healthcare systems have designed primarily to treat acute conditions; specific focus must increasingly apply to people with chronic conditions. It is important to allow People, organizations and software systems to communicate with each other. However, there are different needs and background context of each entity that makes the communication complex, that needs to be identified and integrated [2]. Each uses different jargon, each may have different overlapping or mismatching concept, structures and methods. These all are the consequence of lack of shared understanding. In the process of developing an IT system lack of shared understanding is the reason for difficulties in identifying requirements and in the defining of a specification of a system, different modeling techniques, paradigms, languages and software tools and potentially for reuse and sharing of knowledge [7]. The way that helps to solve the above listed and other problems is to reduce or eliminate conceptual and terminological confusion and come to a shared understanding. Such an understanding can function as a unifying framework for the different viewpoints and serve as the basis for communication, interoperability, re-usability, reliability and specification [3].

2. Related Works

Mukasine A., 2014 [3] Developed an ontology to support chronic type 2 diabetes patients to treat themselves without the need of the involvement of health professionals. Thirugnanam et al., 2013 [5] Conducted a research to develop an ontology-based disease information and their symptom. Alamu., 2014 [1] Developed an ontology for malaria disease. It includes gathering of relevant information from a recognized body about the parasite, the mode of treatment, malaria type, symptom and others, developing an ontology based on the information given and providing a means of remote access for individuals as well as groups who needs the service. Tian., 2014 [6] designed Ontology-Based Decision Support System for Interventions based on Monitoring Medical Conditions on Patients in Hospital Wards.

3. Proposed Methodology

The need for developing personalized ontology based recommending system for chronic patients arises from the drawback of machine learning and the current object-oriented techniques [12]. This model has six components. These are the patient ontology module which contains the patient profile, domain or disease ontology module, the module that integrate the patient ontology with domain or disease ontology, the inference engine that applies some logical rules to deduce information from the knowledge base, the recommendation lists and the user interface to allow users to use the system.

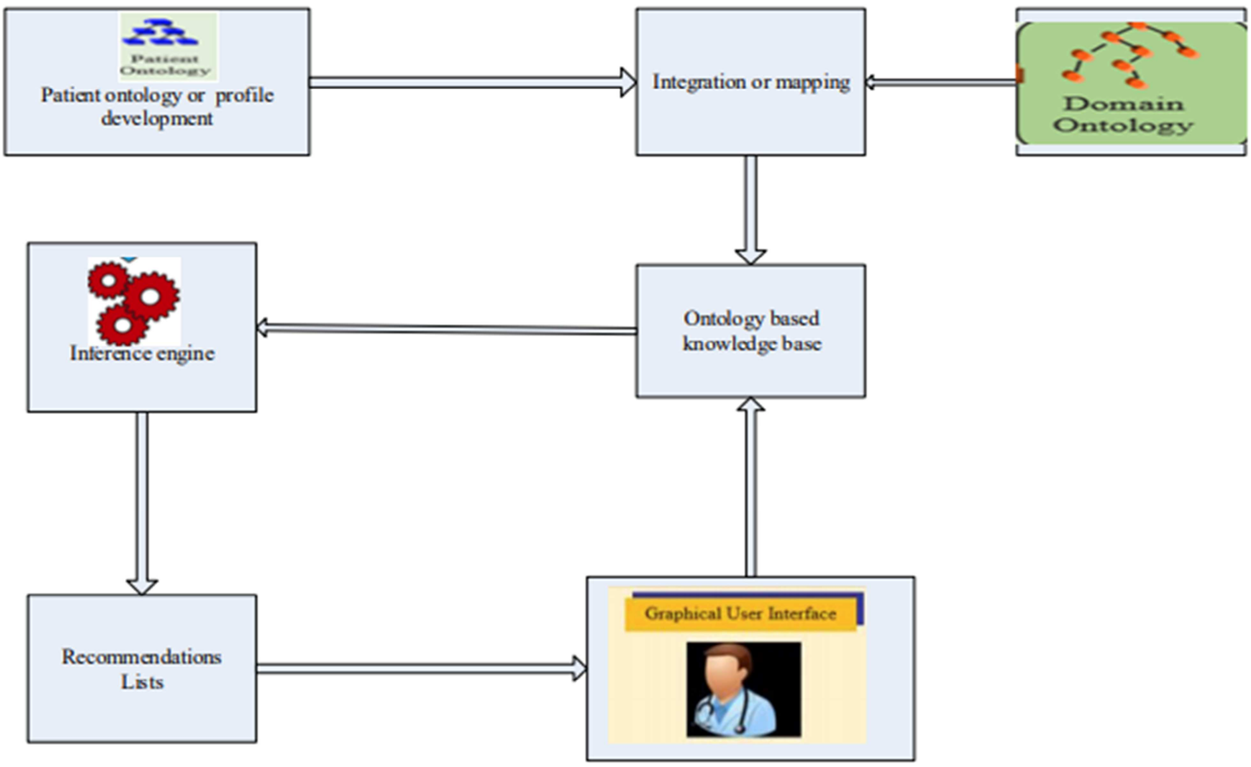

Figure 1. *Architecture of the model.*

3.1. Class and Class Hierarchy

Definition of class and class hierarchy is one of the basic important steps in ontology development process [8]. It is important to organize classes into a hierarchy in the development process. The whole picture of ontology domain has described into class and class hierarchy in protégé environment. Class allows grouping of resources with similar characteristics. It specifies concept of the domain as collection of abstract objects defined with the same values of aspect.

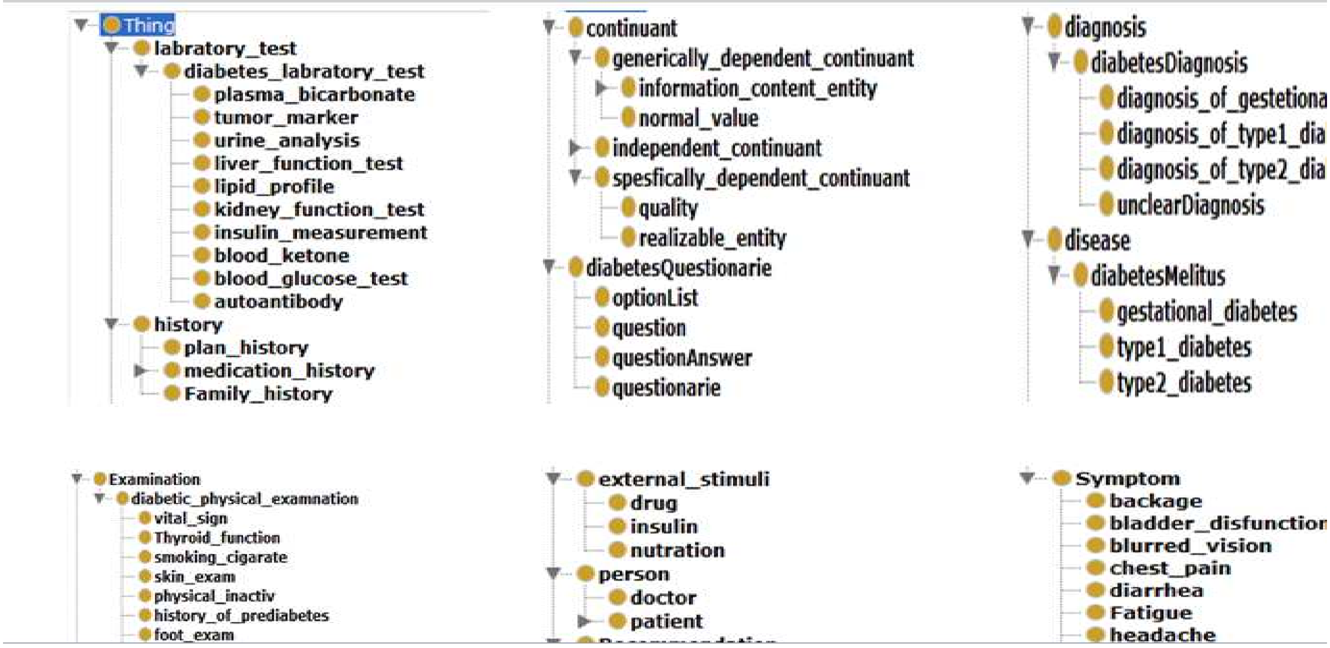

Figure 2. Classes and class hierarchy of our proposed ontology.

3.2. Object Properties of a Class

The creation of object properties in ontology development is to add some restriction onto the class. In web ontology, language (OWL) properties have used to assert relationships between individuals or instances in a domain.

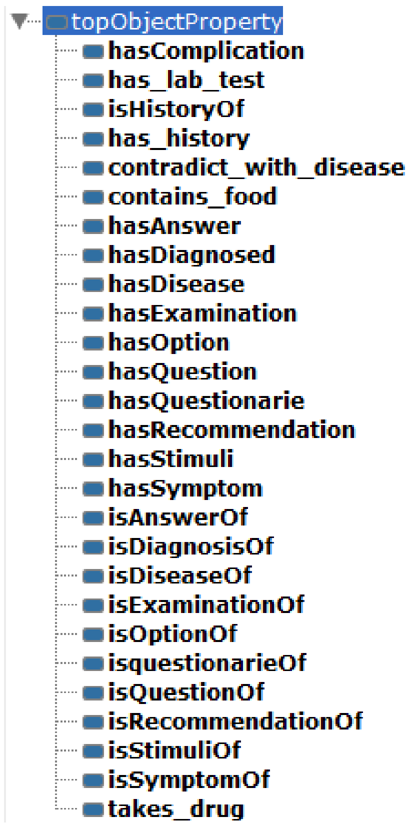

Figure 3. Object properties of our ontology.

3.3. Data Properties of a Class

Also known as attributes. They used to describe classes by assigning their attributes. They have type, label, and value. Attributes have utilized to define semantic relation and characteristics of classes in ontologies.

Figure 4. *Data properties in our ontology.*

3.4. Defining Facet, Range and Domain of the Property

Facets are attribute or characteristics of a property and are used to impose restriction on property value like cardinality restriction (minimum and maximum cardinality restriction), quantifier restriction (existential and universal), and data type value of property (integer, string, date, Boolean, etc.).

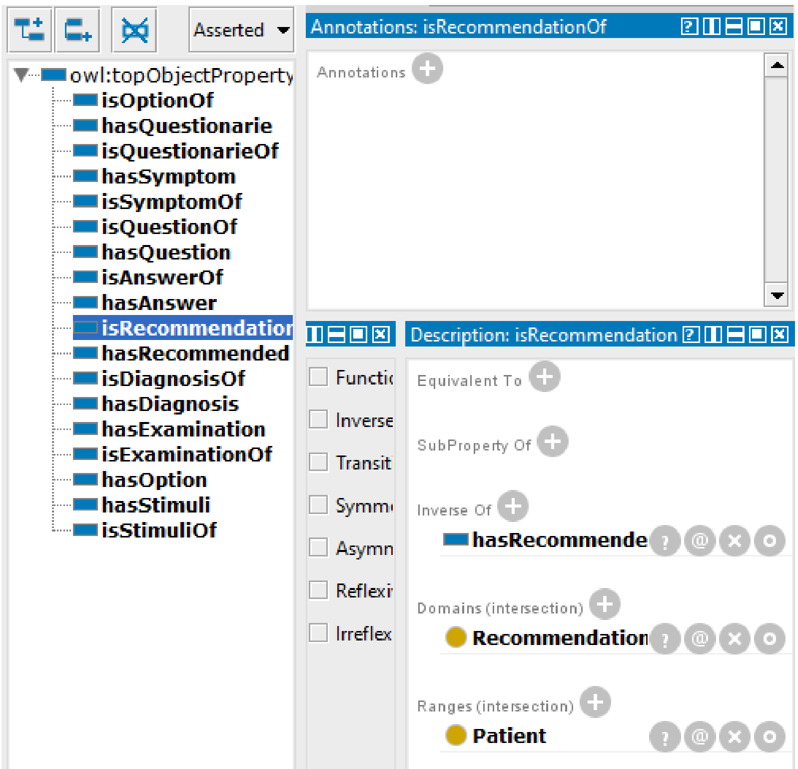

Figure 5. *Facets, domain and range of ontology.*

3.5. Define Instance

The last step of ontology development process is creating instances or individuals related to previously defined classes [13]. Instances or individuals in description logic and are defined as concrete objects of classes. Firstly, we have selected class of individuals to be added. Then we created an individual instance of that class. Instance is the set of individuals associated to the same object and data properties.

3.6. Use of SPARQL to Retrieve Information from Ontology

Having inference model that contains the asserted and inferred statements, we used SPARQL to search and query information in our model. The result should be specific individual patient context, because the model should provide a personalized recommendation for patient self-treatment and diagnosis at home. The user especially in our case the patient can request any queries for different recommendation based on their personal health status and conditions and can access the required self-treatment and diagnosis advises. Some sample SPARQL queries have presented below.

3.6.1. Query for Retrieving Subclass and Superclass Relationship in Our Ontology

PREFIXrdf: <http://www.semanticweb.org/smmb/ontologies/2018/4/diabetestreatmentontology#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
SELECT ?subject ?object
WHERE {?subject rdfs:subClassOf ?object. }

subject	object
blurred_vision	Symptom
kidney_function_test	diabetes_labratory_test
stomack_pain	Symptom
post_prandial_diarrhea	diarrhea
fungal_and_bacterial_infection	Symptom
emphysema	Symptom
lipid_profile	diabetes_labratory_test
gestational_diabetes	diabetesMelitus
tingling_of_skin	foot_symptom
diagnosis_of_type1_diabetes	diabetesDiagnosis
recommendation_of_gestational_diabetes	Recommendation
bladder_disfunction	Symptom
nausea	Symptom

Figure 6. *Sample query result for subject and object relation in the ontology.*

3.6.2. Query for Retrieving Patient Information

PREFIXrdf: <http://www.semanticweb.org/smmb/ontologies/2018/4/diabetestreatmentontology#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
SELECT ?patient ?name?age?gender?type
WHERE { ?patient rdf:hasName?name. ?patient rdf:hasAge ?age. ?patient rdf:hasGender ?gender. ?patient rdf:hasType ?type. }

	patient	name	age	gender	type
1	rdf:Patient3	"Alem Kebede"	"28"^^xsd:int	"Female"	"Gestational diabetes"
2	rdf:patient9	"Fetya muhaba"	"34"	"Female"	"Gestational diabetes"
3	rdf:Patient1	"Bahiru simegn"	"27"^^xsd:integer	"Male"	"type one diabetes"
4	rdf:patient4	"Aster Abebe"	"32"^^xsd:int	"Female"	"type one diabetes"
5	rdf:patient7	"Mohamed Endris"	"22"	"Male"	"Type two diabetes"
6	rdf:patient6	"Habtam Ayalew"	"34"^^xsd:int	"Female"	"Gestational diabetes"
7	rdf:patient5	"Ayalsew beyene"	"27"	"Male"	"type two diabetes"
8	rdf:patient8	"Amanu zeleke"	"12"^^xsd:int	"Male"	"type one diabetes"

Figure 7. *Sample Patient information retrieval.*

3.6.3. Query for Retrieving Recommendation for a Patient

PREFIXrdf: <http://www.semanticweb.org/smmb/ontologies/2018/4/diabetestreatmentontology#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>

SELECT ?patient ?name?type?recommendation WHERE { ?patient rdf:hasName ?name. ?patient rdf:hasType ?type. ?patient rdf:isRecommended ?recommendation. FILTER (?type="type two diabetes") }

	patient	name	type	recommendation
1	rdf:patient5	"Ayalsew beyene"	"type two diabetes"	"Regular blood glucose monitoring to protect your blood glucose, doing regular physical excercise by discussing with your doctor, taking appropraite or balanced diet by discussing with your doctor and other dietetian to protect yourslf from foods that increases your blood glucose level, starting insulin injection is mandatory since your health condition is not good Foods to balance and treat your health problem includes a. take a lots of vegtables d. nuts b. limit processed sugar e. nuts c. Eggs"
2	rdf:patient2	"Almaz abebe"	"type two diabetes"	"since your health status is good you can treat yourself by taking balanced diet and doing physical excercise. in addition to this you must stop drinking alcohol and monitor your blood glucose regularly Common and appropraite foods to be taken are 1. Beans 4. Fish and seafood 2. Legumes 5. Organic dairy products 3. Eggs 6. Peas You can take one drink of alcohol per a day"

Figure 8. *Sample patient recommendation retrieval.*

4. Experimental Results

In the proposed work, system centered evaluation was performed by checking the performance of the system through objective evaluation criteria commonly adopted to measure such system. In this phase testing of the model, testing of case similarity and information retrieval performance using some performance measurement criteria like recall, precision and coverage have performed.

Testing and Evaluation of the Model

System or model testing is the last stage or step in the development process that helps to measure whether the proposed model is met the stated objective or not. In this work, the evaluation has mainly performed in order to determine user acceptance and applicability of our ontology-based patient recommender system in a given area. In the testing process of the model, a total number of 6 peoples are involved in the evaluation process. Among them one gestational diabetic patient, one type 1 diabetes patient, one type 2 diabetes patients and three other domain experts are selected for the evaluation process. First, we have entered patient's personal information to the system. Some of the patient information includes, patient's age, name, sex, feeding habit, religion, types of diabetes they have and other important information. Then the patient answers some major questionnaires, which have presented to them by the model. The questionnaires are some globally standard questions about the diabetes disease. Some of the common questionnaires, which have used in the diagnosis process of diabetes, have discussed in the above section of this chapter. The system needs answers to the questions in order to identify the patient's personal context, since the proposed model provides personalized recommendation for chronic patients. The domain expert is important in this evaluation process in order to see and measure how usable is the model is useful. In order to know the model performance as the number of iterations increases, we used the model for a number of times. We used the model for retrieval of information at least for ten times. In all iteration, we have recorded the result of the iteration. The record used to know whether the model provides relevant recommendation or it is irrelevant.

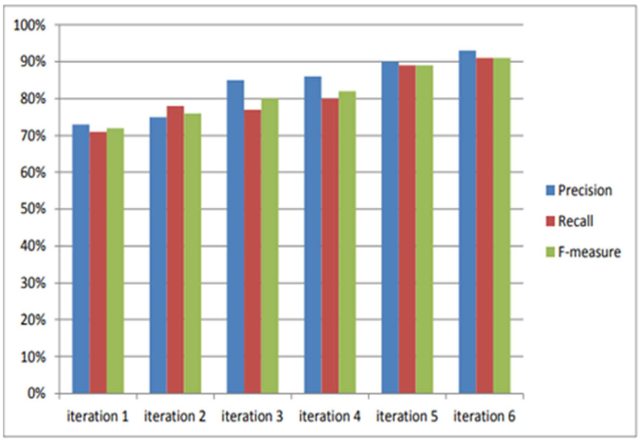

Figure 9. *Performance evaluation result.*

The result from the evaluation process of the model have presented below. Together with the experts, we used the model for ten times. We have grouped the retrieved items into important (relevant) or non-relevant. Then we count and arrange each number in a table format that helps to evaluate the performance of the model. From the given number we can measure precision, recall and accuracy.

From the above result, it can understand that the value of each metrics has increased from iteration to iteration. The increasing in the value of precision indicates that the recommended items are consistent and most important. As the number of iterations increased the percentage of precision increased. It indicates that in order for the user to access most important and consistent information they must rate the system repeatedly. Recall in recommender system shows the ability of a recommender system to provide most of the relevant documents to the specific user based on their interest and their personal context. In this study, the value of a recall increases from one iteration to the next iteration. It indicates that as the number of rating increases the retrieval of relevant items for patients also increases.

In addition to the recommendation performance, we have also evaluated the performance of proposed diabetes ontology in terms of the concepts in the ontology. We depend on the domain experts in this evaluation. In this part of evaluation, we have evaluated the proposed ontology using precision, recall and F-measure. Precision is number of correct concepts in the ontology relative to total concepts in the ontology and recall is the number of correct concepts in the ontology relative to total number of possible concepts in the ontology. F-measure used to balance and simplify the two metrics in measuring performance. In this part of evaluation, we have depended on two-diabetes disease expert. First, they are allowed to see the class in the ontology and to tell the shortage of the ontology. They have identified 51 correct classes in our ontology but the total numbers of class are 56 and tell us there must be 2 other missing that should be included to the ontology.

Precision = 51/56= 91% F-measure= 2PR/P+R

where p= precision and R= recall, Recall = 51/58= 88% F-measure=2*0.91*0.88/0.91+0.88= 89%

The ontology also evaluated in terms of the instance or individuals. The expert checks instances or individuals in the ontology and identified 115 correct instances from the total number of 120 instances. They identified other remaining 5 missing instances in the ontology.

Precision = 115/120= 95% F-measure = 2*0.95*0.92/0.95+0.92= 93%, Recall = 115/125= 92%

The proposed ontology also evaluated in terms of data type and object type property found in it. The have checked the data type and object type properties in the ontology and identified 70 correct data type and object property from the total number of 76 data type and object type properties. They have identified another 4 missing data type and object type property.

Precision = 70/76= 92% F-measure = 2*0.92*0.87/ 0.92+0.87= 89%, Recall = 70/80= 87%

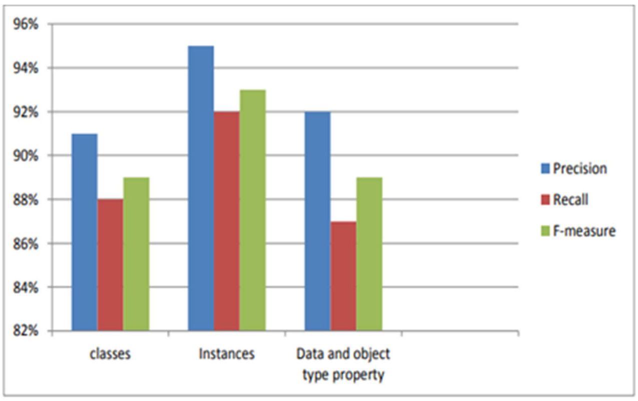

Figure 10. *Performance evaluation result of the proposed ontology.*

5. Conclusion

Chronic diseases are an ongoing, incurable, and long-lasting problem which requires closer follow-up and treatment by both the health professionals and the patient themselves. Designing a recommender system in different domains of life like in e-commerce, healthcare, E-learning, entertainments and others is a well-explored research area. The use of such systems in Ethiopia ranges from rare to none. The existence of recommender system in health domain is not exception from this fact. Hence, the purpose of this study was developing ontology-based recommendation model that support chronic patients to treat themselves and the major deliverable from this research is a recommendation model that have designed following the design science research methodology.

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