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GCXLONTO - A TOOL FOR SEMANTIC INTEGRATION OF MARC 21 BIBLIOGRAPHIC DATA INTO GCONTO

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Abstract

The proliferation of bibliographic metadata has led to an overwhelming voluminous data, necessitating advanced methodologies for effective organisation and retrieval of data. The vast amount of bibliographic metadata available in the Union Catalogue of Gujarat Colleges (GujCat) poses significant challenges in terms of efficient data organisation, search, and retrieval. Traditional methods of cataloguing and indexing often fall short of capturing the complex relationships and nuances within scholarly works. The study explores and created tool named GCXLOnto with the integration of panda library of python to transform MAchine-Readable Cataloging (MARC 21) bibliographic metadata into and excel data and then structured transformation from excel data to Web Ontology Language (OWL) for information retrieval, aiming to enhance the efficiency of search and retrieval processes. In practice, two strategies are used to create and import the data into ontology. One involves manual creation which needs expertise from ontology developers and the second strategy entails converting the available structured data into ontology. The study suggests a way to turn MARC 21 bibliographic data into semantically rich OWL ontology. The evaluation of the framework will be done on a sample dataset of bibliographic metadata available in GujCat. Findings of the study contribute towards the development of advanced systems for managing and accessing bibliographic metadata available to the GujCat.

Keywords:

RDF, MARC 21, GujCat, GCXLOnto, GCOnto

1. INTRODUCTION

Gujarat, with its diverse educational landscape, witnesses a continuous influx of academic publications from numerous colleges across the state. The Union Catalogue of Gujarat Colleges (GujCat) serves as a central repository, aiming to streamline the accessibility of scholarly information. GujCat faces the formidable challenge of managing an ever-expanding volume of bibliographic metadata. Currently, GujCat has around 5 lakh plus unique metadata and 7 lakh plus records withholding details of 40 colleges of Gujarat state [1]. The conventional methods of cataloguing and indexing struggle to keep pace with the dynamic and heterogeneous nature of scholarly works. The study endeavours to introduce a novel approach to transform the MARC 21 bibliographic metadata into excel data and then into OWL by integrating pandas library of python, with a specific focus on the context of the Union Catalogue of Gujarat Colleges database.

Bibliographic metadata is crucial for researchers and scholars seeking valuable information. It is basically an important source of information for researchers and scholars about books, articles that are pertinent to their investigation. However, it might be difficult to find pertinent information in bibliographic metadata, particularly when working with big and complicated datasets. Transforming bibliographic data into semantically enrich representation would help researchers to find the relevant information they need.

For decades, the library community has used the MARC 21 standard for exchanging library data. Transforming bibliographic metadata entails conversion from MARC 21 data into ontology that can be used for efficient search and retrieval. MARC 21 collects significant connected information. The conversion or transformation of MARC 21 constructs into classes, properties, instances, etc. in ontology is accomplished by creating mapping rules between MARC 21 and Ontology. Ontology refers to the knowledge base content for any domain of discourse. The World Wide Web (WWW) allows Internet users around the world to share a wide range of content. Databases, XML data, Excel data, Word documents are among the formats accessible for the information. These sorts of data on the web allow users to obtain information by displaying the content in its original format.

Ontology-based information systems integration is suggested as a solution to the syntactic discrepancies between various specified languages and the gap between schemas and ontologies. Several techniques have been proposed that directly translate relational schemas to ontology languages [15]. In this paper, we suggest an approach to create an ontology data model from an excel data that was obtained from a MARC 21 bibliographic metadata.

Currently, the bibliographic metadata is received in various formats, i.e. MARC 21, Database backup, and Excel data from different colleges across Gujarat state. This data requires pre-processing steps to remove typo errors and special/junk characters and store them in a row database structure. Direct import between ontology and row structure data is not feasible, so this paper suggested a tool to transform it into Excel data and then into ontology. Two processes are created: the first is to transform MARC 21 bibliographic metadata into Excel data, and the second is the semantic integration of heterogeneous data into ontology. The first process includes a mechanism to parse the three-level DDC subject hierarchy from the class number.

1.1 OBJECTIVE

The main objective of this paper is to propose a tool for refining MARC 21 bibliographic metadata into excel data and then into ontology, which can then be utilized for information retrieval.

2. RELATED WORKS

Bibliographic data is complex with various elements used for describing knowledge resources. MARC21 is the prescribed standard to be followed by libraries to create the bibliographic data. It is found that libraries used their data formats to enter bibliographic data or take a subset of MARC elements and/or introduce new elements required quite arbitrarily. Cross walks were attempted to migrate the non-standard bibliographic data to standard formats. However, the semantic approach is being adapted to build formal representation bibliographic data. A significant amount of research has been done on creating ontology from relational databases also.

The approach to build domain-specific search engines using semantic technologies proposed by Han and Kim [2] involves three main steps: (1) building a domain-specific ontology that captures the concepts and relationships in the domain, (2) annotating the documents with semantic metadata using methods for natural language processing, and (3) using the annotation documents and ontology to generate relevant search results. They investigated its efficacy with a medical document dataset. The method proposed by Asfand-E-Yar and Ali [21], creating an ontology model for both flat file and relational databases. After that, Generic model was created but in the final stage, the book details were extracted from the library data by performing a SPARQL query on the data. Although the concept was straightforward and effective and hence it needed automatic mapping and integration techniques.

Sequeda [15] concludes that it is a highly difficult task to build an ontology from scratch or by hand; typically, it calls for a combination of ontology engineer expertise and domain experts' knowledge. Ernestas Vysniauskas [19] suggested a method and generated a tool for transforming the domain ontology described in OWL to RDB. Zhao and Qian [21] described a process that uses the database schema extraction to create ontologies. Relational algebra and rooted graph approaches were used to integrate ontology and they created semantic queries using SPARQL. Using the database API, the relational model was taken out of the database to complete the semantic integration.

Dadjoo and Kheirkhah [14] primary goal is to extract specific Excel components in order to produce a more enriched ontology. Gangemi and Presutti [4] provide a set of ontology design patterns based on the FRBR (Functional Requirements for Bibliographic Records) for modelling bibliographic resources. This involves four levels: work, expression, manifestation, and item.

Metadata can provide more information about entities in an ontology and can help improve the accuracy and efficiency of ontology-based search. Using this argument Alshammari, R., and Alkhalifa [11] proposed a framework for enhancing ontology-based search using metadata. The framework's effectiveness was tested using a case study in the healthcare domain that compared it with a baseline ontology-based search without metadata. Margherita Sini, et. Al [9] proposed a framework for Food, Nutrition and Agriculture (FNA) Journal ontology consisting of all the relationships among the objects including labels in multiple languages. While the user is exploring the interface in their preferred language, they get the result in the selected language. Arora and Gupta [12] presented a framework for incorporating machine learning into an ontology-based search system and demonstrated its effectiveness using a case study in the e-commerce domain. ML can be used to improve the accuracy and efficiency of ontology-based search by learning from user behaviour and feedback.

Similarly, Li et al. [13] framework improves search methods by combining ontology-based techniques with machine learning in the context of Apache Jena. ML algorithms are integrated into the Apache Jena framework, contributing to more effective and intelligent search processes. The integration of ontology and machine learning in Apache Jena provides a promising avenue for advancing search capabilities in complex and dynamic information environments. Ontology-based semantic search is an effective technique and can be used in a variety of sectors, including healthcare, e-commerce, and social media [8].

The Šváb-Zamazal and Svátek [3] argue that conventional keyword-focused search strategies are insufficient for complex bibliographic data, which often contains domain-specific terminology and relationships. They proposed an ontology-based approach involving two main steps: (1) creating an ontology that captures the concepts and relationships in the bibliographic domain, and (2) using the ontology to guide the search process. It leverages structure and semantics of the data to improve search accuracy and relevance. Approach effectiveness was tested on the dataset of bibliographic data in the field of computer science.

3. METHODOLOGY

Transforming MARC 21 bibliographic metadata into OWL ontology, captures the rich semantic relationships between academic entities such as colleges, authors, publications and more importantly relationship between keyword concepts. The integration not only facilitates a more structured representation of data but also unlocks the potential for advanced querying and exploration. The study begins with a data preprocessing phase of bibliographic metadata sourced from diverse colleges across gujarat state, addressing issues of data heterogeneity, inconsistencies, and missing information. Following this, a domain-specific OWL ontology is designed with the name GCOnto using schema.org to encapsulate the hierarchical structures within bibliographical entities. The enriched information is seamlessly integrated into the OWL ontology, creating a knowledge graph that encapsulates the semantic richness of inherent relationships. Process flow consists of two steps i.e. conversion and import as shown in Fig.1. At initial stage data is available in MARC21 format so conversion is required to bifurcate data into data property and object property and then with mapping rules we can import excel data to ontology.

This method aims to improve the efficiency of information retrieval systems by providing a more organized and easily accessible representation of bibliographic metadata. The method involves several key steps:

- **Data Extraction**: Identify and extract key entities and concepts from the bibliographic metadata, such as authors, titles, language, ISBN, and publication details.

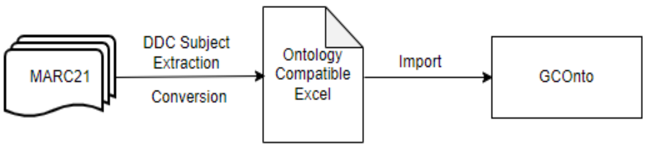

Fig.1. Process flow of GCXLOnto tool

- **Relationship Creation**: Determine the relationships between the extracted entities and concepts, such as co-authorship, publication dependencies, and subject areas.

Ontology creation and import data: Represent the extracted information in a structured format using ontologies, which are formal representations of concepts and relationships. Ontologies can be represented in various formats, such as RDF or OWL. The study used a manually constructed MARC 21 bibliographic metadata set that was plotted, examined, and shown using a variety of pandas modules in python.

4. ONTOLOGY DEVELOPMENT

Ontology refers to the formal representation of knowledge about a particular domain, typically using a vocabulary of terms and the relationships between them. We used schema.org while creating an Ontology from Excel data. Schema.org is a collaborative community project whose aim is to build, maintain, and promote schemas for structured data on the Internet, web pages, and elsewhere.

4.1 TERMINOLOGY OF ONTOLOGY

Ontology terminology and implementations discusses the foundation, authorship, and application of ontologies and reference terminologies, as well as the formalisms required for their use. The Fig.2 shows the GCOnto schema.

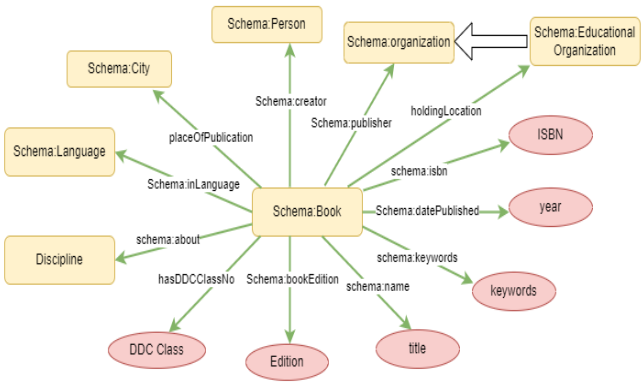

Fig.2. GCOnto Schema

- **Concepts:** Ontologies are composed of concepts or classes that represent entities, ideas, or things within a domain. These concepts are organised hierarchically, with broader, more general concepts at the top and narrower, more specific concepts below.
- **Instances:** Individuals are specific examples of concepts within the ontology.
- **Properties:** Properties define the attributes or characteristics of concepts and instances. Data properties define values and object properties define relationships between concepts.
- **Relationships:** Relationships represent the connections between concepts within the ontology. These relationships describe how concepts are related to one another and can include hierarchical relationships such as "is a" or "is a subclass of" and associative relationships such as "has Subject" or "is related to".
- **Axioms:** Axioms are statements that express constraints or rules within the ontology. Axioms help to define the logical consistency of the ontology and ensure that it accurately represents the domain.
- **Formalization**: Ontologies are typically formalised using a formal language or framework, such as the Web Ontology Language (OWL) or the Resource Description Framework (RDF). These languages provide syntax and semantics for defining the structure and content of the ontology.
- **Reasoning:** Ontologies can be used for automated reasoning, allowing computers to infer new knowledge based on the existing knowledge represented in the ontology.

GCOnto contains some classes from the schema.org and some user defined classes as shown in Fig.3.

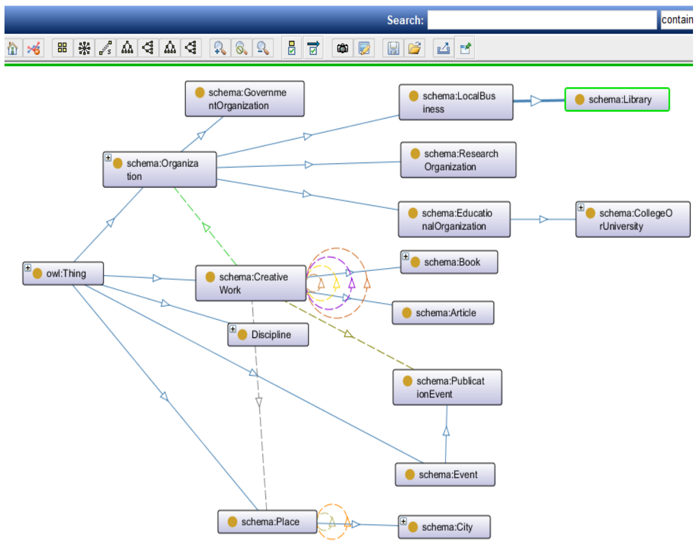

Fig.3. GCOnto Class View

4.2 DATA MODEL

The Excel data defines the conceptual structure of a data and how it is stored, managed, and modified. Current MARC 21 format stores data in row structure form and ontology imports the data in different types of properties so, MARC 21 to Excel transformation tool GCXLOnto is required as shown in Fig.4. This tool accepts starting/ending record id as an input parameter. Various tools and plugins are available to transform the excel data such as Convert2RDF, Excel2RDF, RDF123[5], Karma [6], Celfie plugins [7] but they are not directly compatible with GujCat bibliographic metadata (MARC 21 format) with extraction of DDC subject hierarchy therefore we have created our own tool for data transformation called GCXLOnto. Utilizing structured data and algorithmic logic, it swiftly navigates through the DDC system, extracting relevant subject hierarchies corresponding to provided class numbers. This streamlined process enhances information retrieval, facilitating accurate categorization and organization of resources within libraries and digital repositories. This tool also helps to handle data duplication and data curation to increase the data quality.

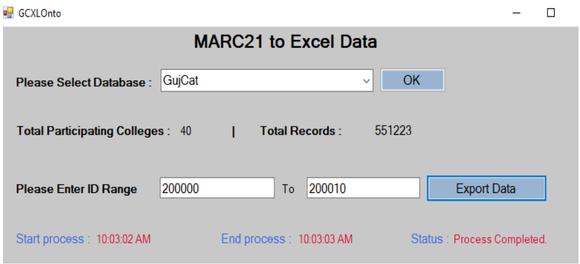

Fig.4. GCXLOnto: MARC 21 to Excel transformation tool

The Fig.5(a) and Fig.5(b) shows the representation of result data generated through MARC 21 to Excel transformation. GCXLOnto also retrieves Dewey Decimal Classification (DDC) three-level subject hierarchies based on class numbers which is also required to enable information retrieval on subject based terms.

SR No	schema:Book	schema:name	schema:creator	schema:bookEdition	schema:isbn	schema:publisher	schema:location	schema:date	schema:inLanguage	placeOfPublication
1	book373670	Prerana Nu Zaranu	AdhiyaJitendra	25thed	978-81-96926-4-9	AdhiaInternational	BDKACCollege	2011	GujaratiLangugage	Ahmedabad
2	book373672	Teo Safal Kem Thaya ?	MardenSwet	9thed	978-81-907514-6-9	RoyalBookCompany	BDKACCollege	2011	GujaratiLangugage	Rajkot
3	book373685	Safal Ane Asarakarak Udhyogpati	DasturBN	1sted	978-81-7790-492-5	PravinPrakashanPvtLtd	BDKACCollege	2012	GujaratiLangugage	Rajkot
4	book374006	Pravasini Prieety Sengupta	ChaudhryBipin	1sted	978-93-82869-54-2	ParshwaPublication	BDKACCollege	2013	GujaratiLangugage	Ahmedabad
5	book374440	Manilal Dwivedi Sanchay	DhirubhaiThakar	1sted	81-260-1456-3	GujaratSahiytaAkadami	BDKACCollege	2002	GujaratiLangugage	Gandhinagar
6	book375037	Kankavati - Gujarati Vratkathao	MeghaniJhaverchand	5threped	978-93-8381-525-8	GurjarGranthaRatnaKaryalaya	BDKACCollege	2018	GujaratiLangugage	Ahmedabad
7	book375079	Ramat Jagat	PatelDinesh	1sted	978-93-84886-69-7	GujaratPrakashan	BDKACCollege	2018	GujaratiLangugage	Ahmedabad
8	book375435	Bibal Na Patro	PaulFatherVarghese	1sted	978-93-82503-07-1	RRShethCoPvtLtd	BDKACCollege	2012	GujaratiLangugage	Ahmedabad
9	book375477	Samajshastra Ma Ankadashastra	KapadiaDrBhanubahenM	1sted	978-81-7057-104-9	AnadaBookDipo	BDKACCollege	2015	GujaratiLangugage	Ahmedabad
10	book375561	England Ka Itihas : BHAG 1	KhannaDrKailash	1sted	81-88775-42-8	ArjunPublishingHouse	BDKACCollege	2012	HindiLanguage	NewDelhi
11	book373689	Gazal	AjmeriSuman	1sted	891-81-7790-077-3	PravinPrakashanPvtLtd	BDKACCollege	2015	GujaratiLangugage	Rajkot

Fig.5(a). MARC 21 to Excel transformation tool outcome

SR No	schema:Book	hasDDCClassNo	schema:about	schema:about	schema:about	schema:keyword
1	book373670	153	Philosophy&psychology	Psychology	Mentalprocesses&intelligence	Mental processes & intelligence,Smart Work, Mind, Subconscious Mind, Memory Power, Spiritual Quotient,Success, Happy, Life,Smart Work, Sharp Work
2	book373672	131	Philosophy&psychology	Parapsychology&occultism	Parapsychological&occultmethods	Success,Hard Work
3	book373685	158	Philosophy&psychology	Psychology	Appliedpsychology	Successful And Effective Enterpreneur,Start Up
4	book374006	891	Literature	Otherliteratures	EastIndo-European&Celticliteratures	Travel - Gujarati Literature,Travelogue - Gujarati Literature
5	book374440	171	Philosophy&psychology	Ethics	Ethicalsystems	Ethical systems
6	book375037	394	Socialsciences	Customsetiquette&folklore	Generalcustoms	General customs
7	book375079	793	Arts&recreation	Recreational&performingarts	Indoorgames&amusements	Indoor games & amusements
8	book375435	225	Religion	Bible	NewTestament	New Testament
9	book375477	314	Socialsciences	Collectionsofgeneralstatistics	GeneralstatisticsofEurope	General statistics of Europe
10	book375561	942	History&geography	HistoryofEurope	England&Wales	England & Wales
11	book373689	891	Literature	Otherliteratures	EastIndo-European&Celticliteratures	Gujarati Poem,Urdu Literature,GAZAL

Fig.5(b). MARC 21 to Excel transformation tool outcome

4.3 ONTOLOGY MAPPING

After creating an ontology schema, the next step is insertion of data value to the ontology. We can insert data to ontology using creating individual instances with the value but it is a time taking process. When Excel data constructs are mapped to Ontology, data is immediately mapped to instances or individuals, attributes are mapped to properties, and sheets are mapped to Ontology classes.

Irina Astrova et al. [21] creates an ontology from SQL scripts in RDBMS, matching SQL constructs with their corresponding ontology constructs.

Zhou et al [22] generates an Ontology generator from RDB by using reverse engineering to retrieve metadata. Direct mapping allows any data structure's properties to be immediately mapped to ontology structures. So, here we have introduced new logic which accepts two input parameters as shown in Fig.6.

One parameter is ontology schema URI and another is output generated excel data through the first step of the GCXLOnto tool as shown in Fig.4 and import to GCOnto by following the algorithm steps mentioned in Fig.7 using panda library.

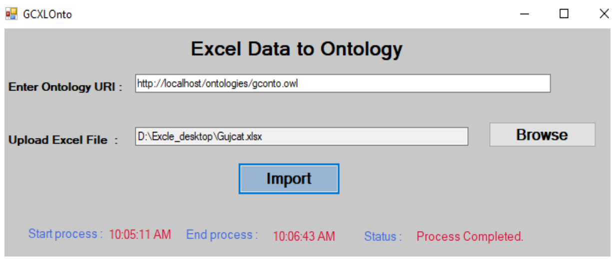

Fig.6. GCXLOnto: Excel data to GCOnto

The Fig.7 shows the sample pseudo code of panda library of python to transform GujCat excel data to ontology format as below:

```
Importing Panda library and RDFLib for Graph

Define excel_to_owl(excel_file, ontology_uri, output_file):
    # Read Excel Data
    df = pd.read_excel(excel_file)

    # Create RDF graph
    g = Graph Generation()

    # Define a namespace for the ontology using XL spreadsheet
    ns = Namespace(ontology_uri)

    # Iterate through Excel data and create RDF triples
    Begin
        While (Data is not empty)
            # Create individual
            individual_id = row.get('BookID', index)
            individual_uri = URIRef(ns + f"Individual_{individual_id}")
            Add your Individual URI

            # Create properties dynamically based on column headers
            for column, value in row.items():
                if pd.notna(value):  # Skip NaN values
                    property_uri = URIRef(ns + f"{column}_{individual_id}")
                    g.add((individual_uri, property_uri, Literal(value)))

            # Save RDF graph to a file
            g.serialize(destination=output_file, define your format)
        End
    End
    print("GCOnto Created.")

# Example Usage
excel_file_path = 'gujcat.xlsx'
ontology_namespace = 'https://ontologies/gconto.owl#'
output_owl_file = 'gconto.owl'

excel_to_owl(excel_file_path, ontology_namespace, output_owl_file)
```

Fig.7. Pseudocode using panda library to transform GujCat excel data to ontology

Executing the above script will generate gconto.owl file as an output and opening of file into protege as shown in Fig.8. OWL is a more comprehensive vocabulary description language that may be used to describe classes and their relationships. Remember that the specific implementation details will depend on your programming framework or architecture, the design of your web interface, and the requirements of your application. Adjust the code accordingly based on these factors. The Fig.9 shows visual representation of GCOnto entities associated with different object and data properties.

4.4 EVALUATION

GCXLOnto is intended to help domain experts acquire knowledge that can then be utilized to enhance ontology. GCXLOnto was created to fill this need and fits the criteria specified in the method section. However, such methods continue to play an important role in the creation of ontology.

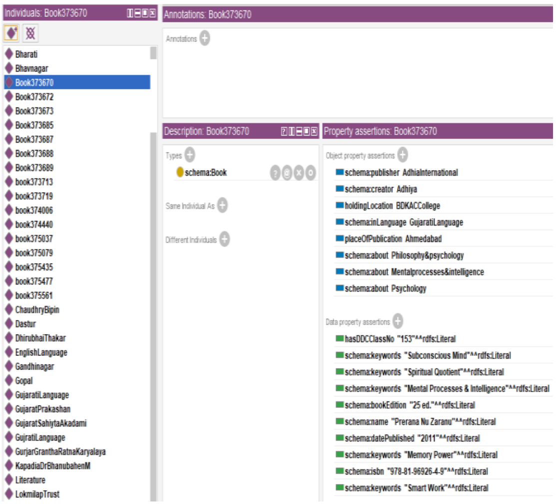

Fig.8. GCOnto Individuals with properties in Protégé editor

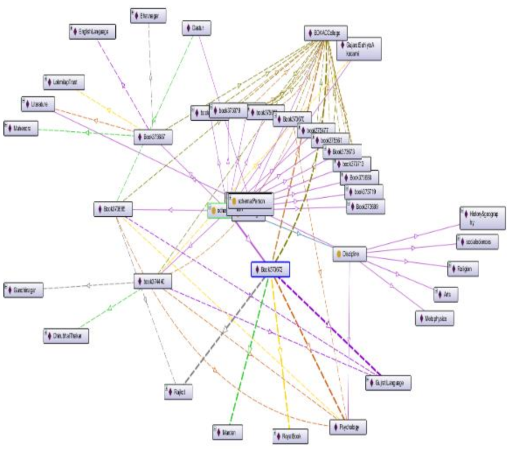

Fig.9. Visual representation of GCOnto instance relationship

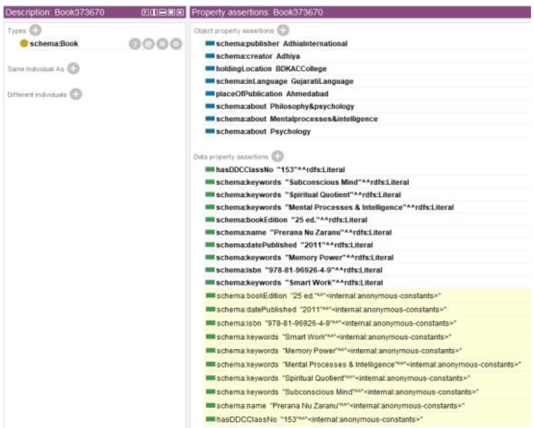

Fig.10. HermiT Reasoner in Protégé editor

The study envisions that the integration of OWL ontology will significantly augment the search and retrieval mechanisms within the Union Catalogue of Gujarat Colleges (GujCat). To infer the knowledge from the GCOnto, HermiT reasoner is used shown in Fig.10. The primary purpose of HermiT reasoner is to validate the ontology and reasoning automation. By incorporating semantic querying, users will not only retrieve precise matches based on keywords but also explore the underlying ontological relationships. The study outcome as a transformative framework includes a more efficient and intelligent system that enriches MARC 21 bibliographic metadata through OWL ontology and enhances the scholarly exploration experience within the unique context of GujCat. The Fig.11 shows the output generated through SPARQL query execution in GCOnto.

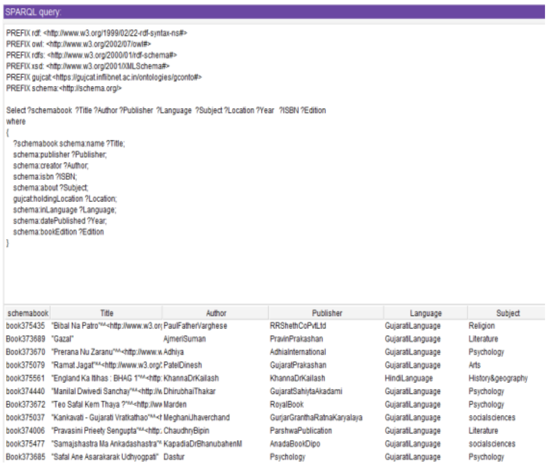

Fig.11. SPARQL query result in Protégé editor

5. CONCLUSION AND FUTURE WORK

GCXLOnto provides a method to transform a heterogeneous dataset into ontology without the usage of a traditional ontology building tool. The approach of using pandas library of python to transform the MARC 21 bibliographic metadata and OWL ontology for GujCat has the potential to significantly enhance efficiency and effectiveness of search and retrieval, and to improve the overall user experience for researchers and students. The use of OWL ontology will make the new bibliographic metadata available or attempt changes in existing data, ensuring its accuracy and relevance. The use of transformed OWL ontology will enable more sophisticated query expansion, semantic search, and faceted navigation to create a more advanced GujCat.

Further, the use of machine learning approaches for improving the accuracy and relevance of search results in the GCOnto can be explored. Also, the algorithms can be integrated for identifying patterns and trends in the bibliographic metadata, such as co-occurrence of authors, keywords, or subject areas. It will help to identify new research areas, connections between disciplines, and other insights that could be useful for researchers and students. Overall, using OWL ontology for transforming MARC 21 bibliographic metadata into an advanced GujCat has the potential to significantly improve the efficiency and effectiveness of search and retrieval, and to enhance the overall user experience for researchers and students.

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