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Original Research

Designing a Metadata Ontology Model for Semantic Modeling and Representation of Scholarly Journal Articles: A Case Study of ISC Journals

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Abstract

One of the new approaches to organizing journal articles is using Semantic Web technologies and new "Semantic Publishing" methods based on the ontological models for semantic modeling and representation of these publications. This study aims to design the metadata ontology model for semantic modeling and representation of scholarly journal articles. This research was *carried out using the* content analysis method. The study population includes articles published in ISC journals (i.e., journals indexed in ISC). A sample of 200 articles from a Persian journal (i.e., "*Iranian Journal of Information Processing & Management*") and an English journal (i.e., "International Journal of Information Science and Management (IJISM)") were considered for semantic modeling and representation using the metadata ontology model. The data-gathering method was a *systematic observation*, and the data-gathering tool was a checklist based on the Semantic Publishing and Referencing Ontologies (SPAR Ontologies). This research identified the metadata entities required for semantic modeling and representation of ISC scholarly journal articles. Then, the metadata ontology model was designed using Protege (an ontology editor) and the RDF representation of the model was created in RDF/XML Syntax. After designing the metadata ontology model, the RDF graph of this model was developed to analyze the entities and relationships between them, and its results were analyzed. The results of RDF graph analysis show that the design of the ontology model and the creation of the RDF links between entities significantly impact the semantic description and representation of metadata entities of the ISC scholarly journal articles and the network of relations between them.

Keywords: Metadata Ontology Model, Scholarly Journal Articles, Semantic Publishing, Semantic Modeling and Representation, SPAR Ontologies.

Introduction

During the past years, the emergence of information and communication technologies has created changes in the library environment regarding managing and organizing scientific publications, methods, tools, and how to provide services. However, these systems have various limitations, especially in displaying relationships between scientific journals in the bibliographic world. These have weakened their efficiency in providing access to the resources

users need. Describing, representing, and showing these relationships in the context of scientific publications and especially journal articles, in addition to structuring data, provides the possibility of retrieving related articles and authors, accurately determining the type of relationship between bibliographic entities, providing citation analysis and displaying co-authorships in library systems.

Considering the shortcomings and limitations of library systems, especially in terms of describing and representing journal articles, and the necessity of improving user interaction with library systems, the designers of these systems have been looking for mechanisms to strengthen them. To solve these problems, one of the issues that have been paid attention to by librarians and producers of library systems in different countries is the use of Semantic Web technologies and new methods of "semantic publishing" based on ontological patterns to represent the bibliographic world (including all kinds of books, journals, projects, reports, etc.). The bibliographic world is a world of recorded knowledge; it is a universe of all information resources (Drobíková, Odehnalová, Juranová, Králová & Svatoš, 2016).

A significant part of the bibliographic world is made up of journal articles. Therefore, it is possible to model and represent the semantics of scholarly journal articles using the methods of semantic publishing and the application of ontology. Semantic publishing is the semantic enhancement of an intellectual work to improve its discoverability, interactivity, openness, aand (e-) usability for both humans and machines through the web and Semantic Web technologies and standards (Peroni, 2017). One of the most essential tools used in semantic publishing is "ontology." An ontology is an explicit formal conceptualization of a particular domain of interest. Ontology is commonly used as a structure capturing knowledge about a specific area by providing relevant concepts and relationships between them (Brank, Grobelnic & Mladenic, 2005). Ontologies have different types. One of them is metadata ontology, which deals with the representation of metadata entities and their relationships through metadata elements in the context of the bibliographic world. Journal articles, as an essential part of the bibliographic world, can be described and modeled using the metadata ontology model.

In the Semantic Web community, choosing well-established ontologies as the foundation for data modeling is highly recommended. This approach greatly facilitates the sharing and exchanging of published data (Hannemann & Kett, 2010). Because they enable more sophisticated functionalities in developing knowledge management and information retrieval applications, ontologies improve the efficiency and consistency of resource descriptions. Standards like the Resource Description Framework (RDF), RDF Schema (RDFS), and Web Ontology Language (OWL) provide frameworks for sharing standard definitions, descriptions, and relationships within a subject domain (Sini, Salokhe, Pardy, Albert, Keizer & Katz, 2007).

These factors, along with other capabilities of ontologies in semantic modeling and representation of scholarly publications, have caused some ontology design projects, such as SPAR ontologies, SWJ ontology (ontology designed for "Semantic Web Journal" modeling), etc., to transform library systems into systems with more semantic capabilities. Since 2010, when there was no rich and suitable ontology to create correct, explicit, and logical descriptions of all dimensions of scholarly publication, Peroni and Shotton (2018) developed a set of complementary and orthogonal ontologies to describe the main aspects of publications. These efforts led to the creation of SPAR ontologies (ontologies designed for semantic publishing and referencing) as a set of ontological modules that enable the description of various aspects of

scholarly publications using Semantic Web technologies.

The SPAR project is a combination of several ontologies. Each group of ontologies has a special application. These applications include:

1) Description of various textual publications (such as books, conference proceedings, magazines, etc.);

2) Representation of document components, both structural (such as chapter, section, paragraph, ...) and rhetorical (such as discussion, introduction, and conclusion, list of references, figures, appendices, etc.);

3) Description of the roles of participating agents in the publishing process (such as authors, editors, reviewers, publishers, etc.);

4) Representation of scientific collaborations;

5) Bibliographic data analysis; and

6) Describe the publishing workflow steps and processes (Fathian Dastgerdi, 2020).

Figure 1 shows SPAR ontologies and their relationships with other models.

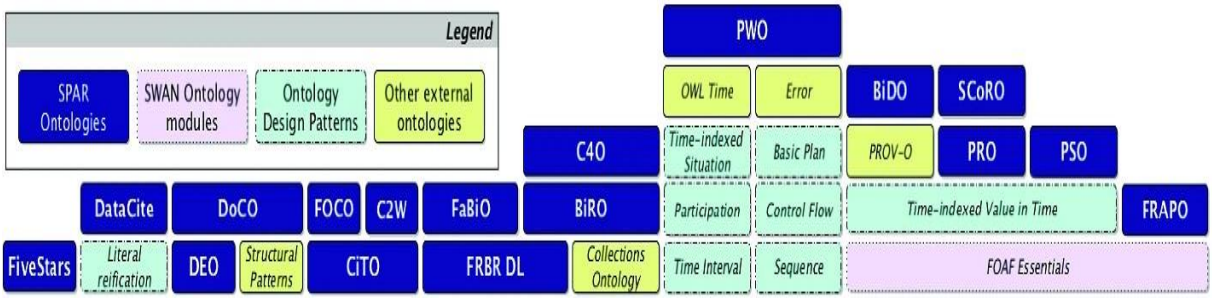

Figure 1: SPAR Ontologies and their Relations with Other Models (Peroni & Shotton, 2018)

According to Figure 1, ontologies FaBiO, DoCO, DataCite, DEO, and FRBR-DL are related to describing bibliographic information of various types of sources and their sections. BiRO, CiTO, and C4O ontologies are used to describe the citations of scientific publications. PRO, PSO, PWO, SCoRO, FRAPO, and FR ontologies are related to the description of publishing workflow steps, and BiDO and FiveStars ontologies are used to describe metrics and statistical data of bibliographic resources (Fathian Dastgerdi, 2021).

The Islamic World Science and Technology Monitoring and Citation Institute (ISC), as one of the leading organizations for organizing scientific publications and providing access to the most comprehensive scientific and technical information in Iran, especially for journals, provides access to ISC databases to describe and represent a variety of scientific publications, such as Persian and English Journals, conference articles, books, theses, etc. The Persian and Latin Journal articles form an important part of the ISC databases. More than 10,000 Journals and over 7 million articles are available to users through this database. ISC Institute, to achieve its goals and missions, has moved towards using semantic web technologies and creating ontologies. In Iran, a comprehensive model for the design of metadata ontology based on SPAR ontologies to model and represent journal articles from various aspects has yet to be presented, so ISC decided to provide this model. ISC through the participation of its publications in the Semantic Web context, provides the possibility of modeling the bibliographic data of the journal articles from the semantic dimension. This model will be one of the basic requirements for

implementing other Semantic Web technologies (such as Linked Data) in the ISC databases. Based on this, it is necessary to conduct comprehensive research to design this model. For this purpose, it is essential to identify the metadata entities and properties required for semantic modeling and representation of ISC scholarly journal articles from various dimensions, including the description of document components, citations, scientific roles and collaborations, metrics, and bibliometric data, publishing workflow steps and processes, publication status of articles, etc.

Literature Review

Fathian Dastgerdi (2021) investigated the application of Semantic Web technologies in the modeling and semantic representation of scientific publications (such as articles, books, theses, etc.). SPAR ontologies and other related sources were examined in order to conduct the research. In general, the significant advantages of semantic publishing in terms of changing the method of publishing and sharing research data, improving search capability, enabling more substantial interaction with users, creating intelligent interfaces and *reasoners*, etc., reveal the need to pay more attention to this area in the bibliographic centers and scientific institutions of Iran.

Scientific innovation depends on identifying, integrating, and reusing the products of previous research. Shotton, Portwin, Klyne, and Miles (2009) investigated how recent advances in web technologies (particularly technologies related to data and metadata publishing) could support this process by providing semantic enhancements to journal articles while publishing scholarly journals. They illustrated this by describing their semantic enhancements to a recent biomedical research article from *"PLoS Neglected Tropical Diseases,"* enriching its content and improving data access. These semantic enhancements included the provision of live DOIs and hyperlinks, semantic markup of textual terms with links to related information sources, interactive figures, a re-orderable reference list, a document summary, etc. They also published machine-readable RDF metadata about the article and the references it cites, for which they developed a Citation Typing Ontology, CiTO.

The Live OWL Documentation Environment (LODE) was introduced by Peroni, Shotton, and Vitali (2012). It is an online service that considers both ontological axioms and annotations and orders these with the appearance and functionality of a W3C Recommendations document. This system automatically generates a human-readable description of any OWL ontology (or, more broadly, an RDF vocabulary). One of the SPAR ontologies, FaBiO (FRBR-aligned Bibliographic Ontology), was used in this study. In 2014, Osborne, Peroni, and Motta introduced a method for authors clustering based on citation distributions. They also presented the Bibliometric Data Ontology (one of the SPAR ontologies) as an ontology to facilitate the formal representation of these clusters. With the help of this technique, it is possible to formulate queries that accurately predict future citation behaviors while accounting for an author's past citation behavior.

Using Dante Alighieri as a case study, Bartalesi and Meghini (2015) examined the application of ontology to represent the knowledge of literary texts. They investigated and reused a few classes and properties from three SPAR ontologies, DoCO, FaBiO, and CiTO to characterize text structure, textual publication type, and bibliographic citations. Tapia-León, Santana-Pérez, Poveda-Villalón, Espinoza-Arias, Chicaiza, and Corcho (2019) proposed an extension to the BiDO ontology, specifically to BiDO Standard Bibliometric Measures which

provide descriptions of bibliometric measures. The BiDO Standard Bibliometric Measures is part of the SPAR Ontology Network. It enables the description of categorical and numerical bibliometric data, including the journal impact factor, author citation count, and h-index. These metrics can be applied to assess researchers' contributions to science. They are insufficient. Therefore, Tapia-León et al. (2019) constructed an extension to reorganize the BiDO ontology using the NeOn Methodology. This extension allows the number of research documents, citations from papers, and publications in high-impact journals to be represented and measured based on the area and discipline.

This section investigated the literature related to SPAR ontologies and ontologies designed to represent the area of publishing and bibliographic entities. However, in Iran, some researchers have focused on the design of metadata ontologies to describe the bibliographic world (including books, articles, etc.). However, the use of SPAR ontologies for modeling scholarly publications and significant articles has not been investigated. In other countries, researchers have studied the area of semantic publishing from different dimensions. They have discussed the expansion of SPAR ontologies and using one or more SPAR ontologies in other projects and new developments in this area. The lack of attention to semantic publishing in Persian literature and the lack of researches that investigate the use of SPAR ontologies in modeling the entities of the bibliographic world (especially journal articles) indicate the need for more attention and practical activities, and conducting research by experts in the area of publishing in Iran.

Materials and Methods

This research used the content analysis method to identify and analyze metadata entities related to modeling and semantic representation of ISC scholarly journal articles using SPAR ontologies. The study population includes articles published in ISC journals (i.e., journals indexed in ISC). A sample of 200 articles from a Persian journal (i.e., "*Iranian Journal of Information Processing & Management*") and an English journal (i.e., "International Journal of Information Science and Management (IJISM)") were considered for semantic modeling and representation using the metadata ontology model. It is worth mentioning that this model can be used for all scholarly journals and has no restrictions regarding the coverage of articles and journals. The data-gathering method was a *systematic observation,* and the data-gathering tool was a checklist based on the Semantic Publishing and Referencing Ontologies (SPAR Ontologies).

First, this research identified the metadata entities required for semantic modeling and representation of ISC scholarly journal articles. Then, the metadata ontology model was designed using Protege (an ontology editor), and the model's RDF representation was created using RDF/XML Syntax. After designing the metadata ontology model, the RDF graph of this model was designed to analyze the entities and relationships between them, and its results were analyzed. The steps of this research are presented in Figure 2:

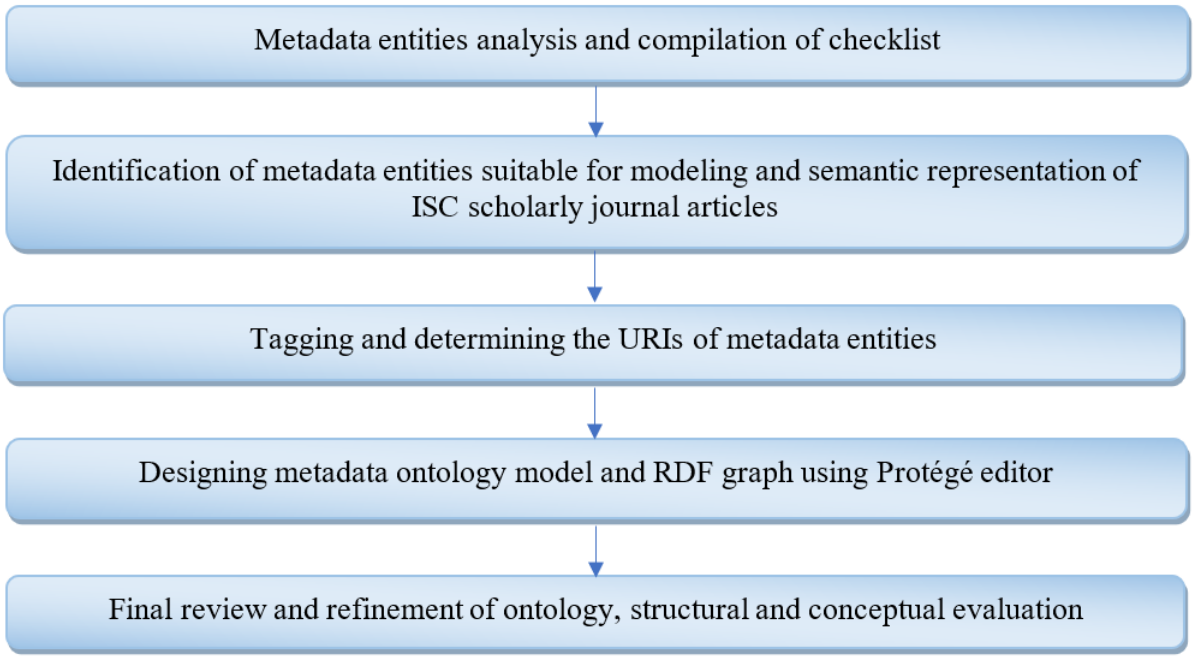

Figure 2: Research Steps

Results

This section presents the method for designing a metadata ontology model for the semantic representation of ISC scholarly journal articles using Protege 5.5. This section describes the process for defining classes, properties, and instances/individuals in the ISCOnt ontology model. In this ontology model, all classes, properties, and individuals have been extracted from the "*Iranian Journal of Information Processing & Management*" and the "International Journal of Information Science and Management (IJISM)." To design this model, first, all the classes and relationships identified for the semantic modeling of the ISC journal articles according to the checklist, were entered into the Protege editor and a hierarchically arranged structure was created. In this way, the classes were defined in the Classes section and the Class Hierarchy window, and properties were also defined in the Object Properties, Data Properties, and Annotation Properties sections. Object properties define relationships between individuals whereas data properties define literal values associated with individuals. Figure 3 shows the classes defined in the ISCOnt ontology. Figure 3 also shows the instances defined for the JournalArticle class (under the Instances icon) and the restrictions created for the class, e.g., "part of some JournalIssue," indicating that the journal article is part of a specific journal issue.

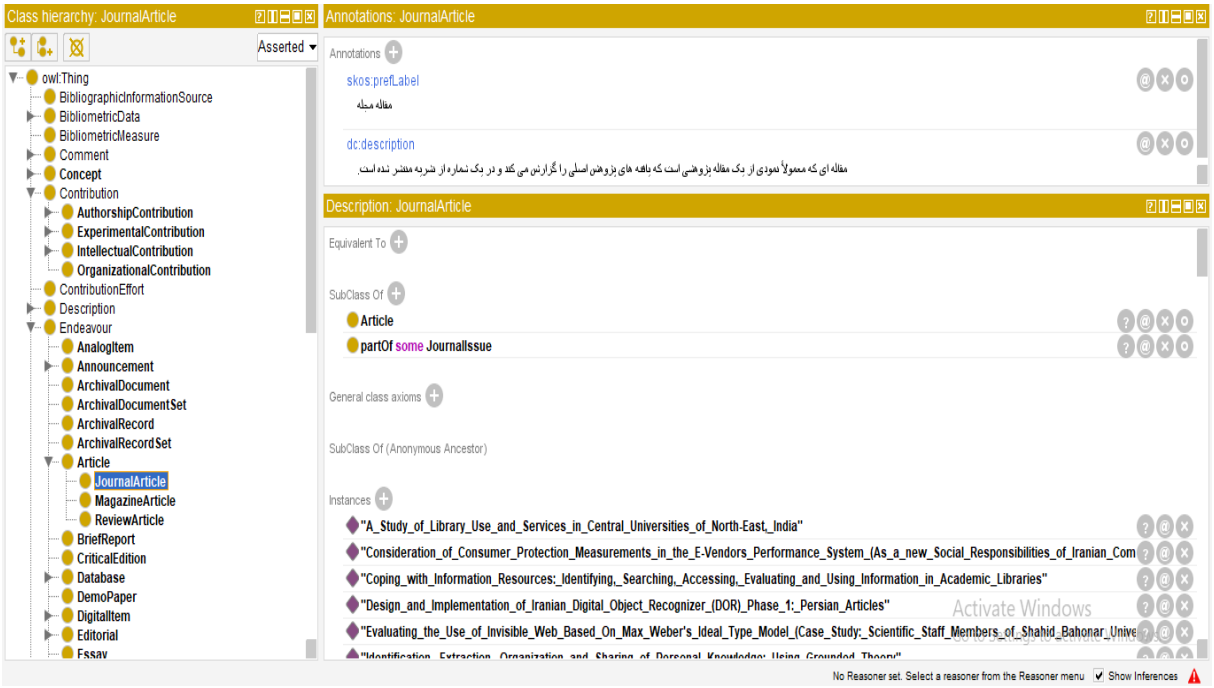

Figure 3: The Classes Defined in the ISCOnt Ontology

After defining the classes, the relationships that establish the connection between the classes must be defined (Figure 4). At this point, all the relationships have been described in the Object Properties section. The reason for defining relationships as Object Properties is that each of these relationships can connect instances of different classes. For example, as shown in Figure 4, the creator relationship can relate an instance of the "Author" class to an example of the "Endeavour" class (which includes all types of scientific documents e.g. articles, reviews, reports, editorials, etc.).

In Figure 4, the creatorOf property is asymmetric and irreflexive. Also, according to the figure, the "creatorOf" property is the "Inverse Of" Creator property. In the Domains and Ranges icons, the Author and Endeavor classes are specified as the domain and range of the relationship, respectively.

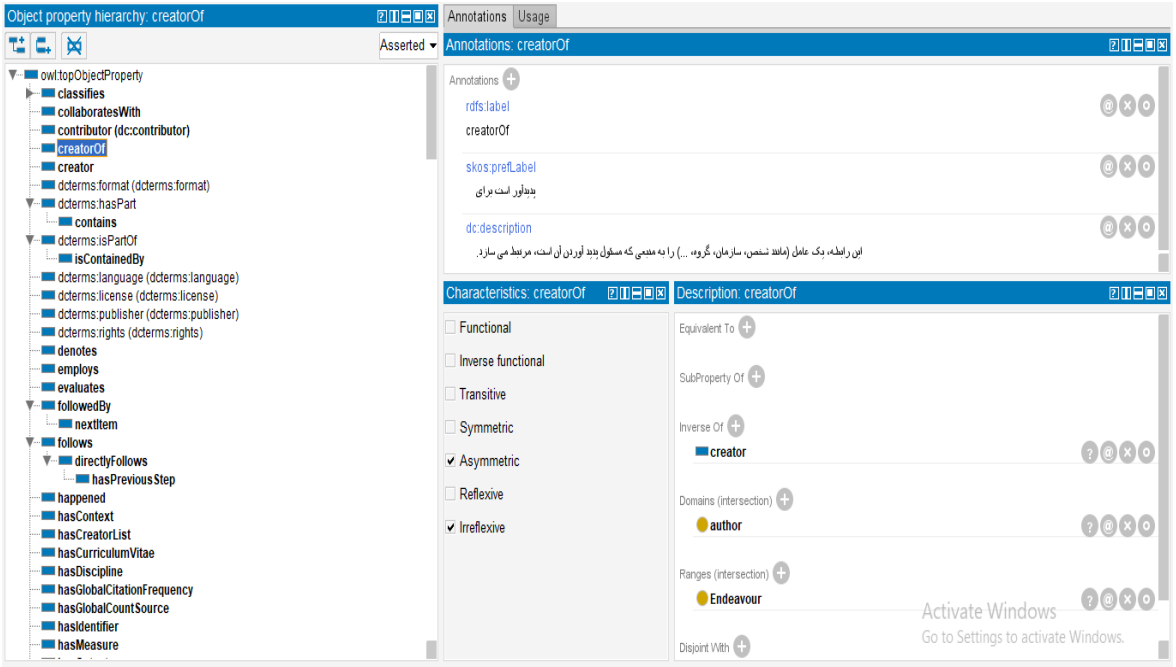

Figure 4: Object Properties Defined in the ISCOnt Ontology

Data Property is another property in ontology that defines literal values associated with individuals. Figure 5 shows a view of these kinds of relationships. Here, there is also a hierarchical relationship between the properties. According to the figure, the range of this relationship is a data type (xsd: string).

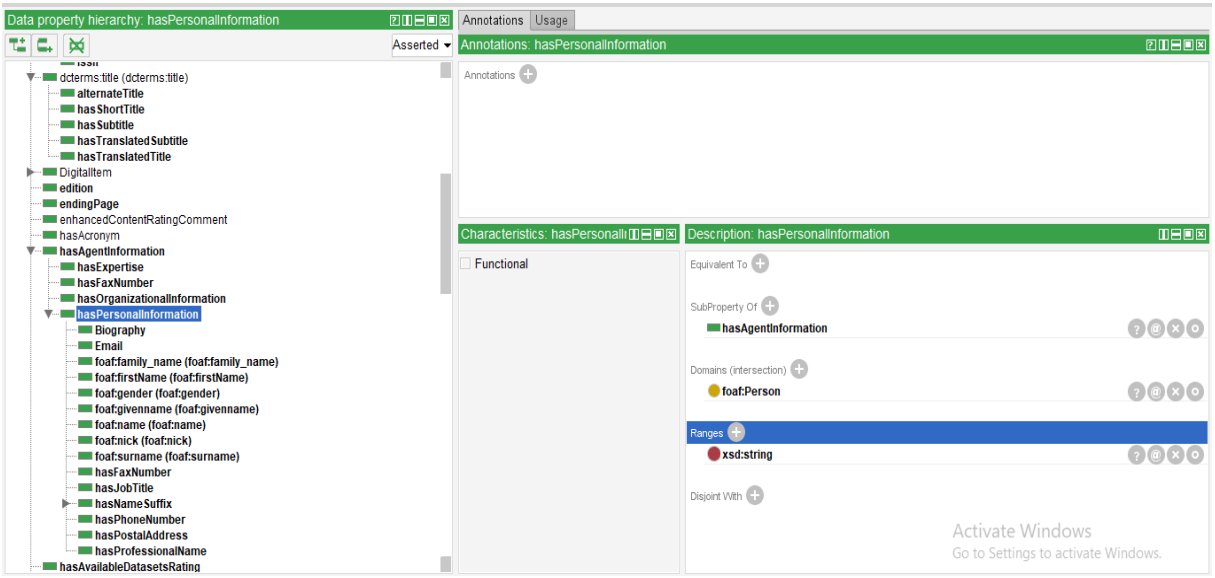

Figure 5. Data Properties Defined in the ISCOnt Ontology

After representing the relationships in the ontology, defining the instances of classes is necessary. In the Protege, the Individuals section is used to determine cases. In this phase, instances related to ontology classes are entered into the Individuals window. Then, as you click on each instance, three windows, including "Annotations", "Description," and "Property Assertions," appear for the desired instance,

where you can define instances in the ontology.

For example, in the ISCOnt ontology, “Dr. Mohammad Reza Ghane” is a member of the Author class. In addition, he has other roles (e.g., reviewer, editorial board member) and the responsibilities of **Managing Editor** and **Executive Editor** of IJISM (International Journal of Information Science and Management). Figures 6 and 7 show the description of “Dr. Mohammad Reza Ghane” in the Individuals section of the ISCOnt ontology. As shown in Figure 6, the Annotations window provides some annotation properties such as Farsi and English labels (rdfs: label and skos:prefLabel), descriptions (dc: description), CV, and an image of him. The Description window displays the classes (types) he is a member of. For example, the class "Vol.15-No. 2 (2017)” represents an issue of IJISM in which his articles were published and Author and Editorial Board classes that represent his different roles in IJISM.

The Property Assertions window displays object and data properties related to Dr. Ghane. The relationships between “Dr. Mohammad Reza Ghane” and other individuals are defined in the Object Property Assertions window. For example, he currently holds the role of managing editor, which is defined with the “holdsRoleInTime” object property (we can use the relation “holdsRoleInTime” to describe the role of a person in a specific time). He also authorizes articles such as "Design and Implementation...", "Identifying Information...", etc., which appear in this window via the CreatorOf relationship. In this section, all of the entities displayed have links; through these links, it is possible to directly access their pages. It is worth noting that about 300 object properties are defined in the ISCOnt ontology to describe all kinds of relationships between instances.

The defined data properties for Dr. Mohammad Reza Ghane are displayed in Figure 6. For Dr. Ghane, some data properties, like his page address in IJISM magazine and personal information such as phone number, email, work address, job title, etc., can be described, as shown in Figure 6. It is important to note that the ISCOnt ontology model has more than 160 data properties for entity definition. Additionally, in Figure 6, the “Same Individual As” icon can be used to identify similar individuals. For instance, if Dr. Ghane appears in the articles under various names and pronunciations, it can be specified that all his names belong to him.

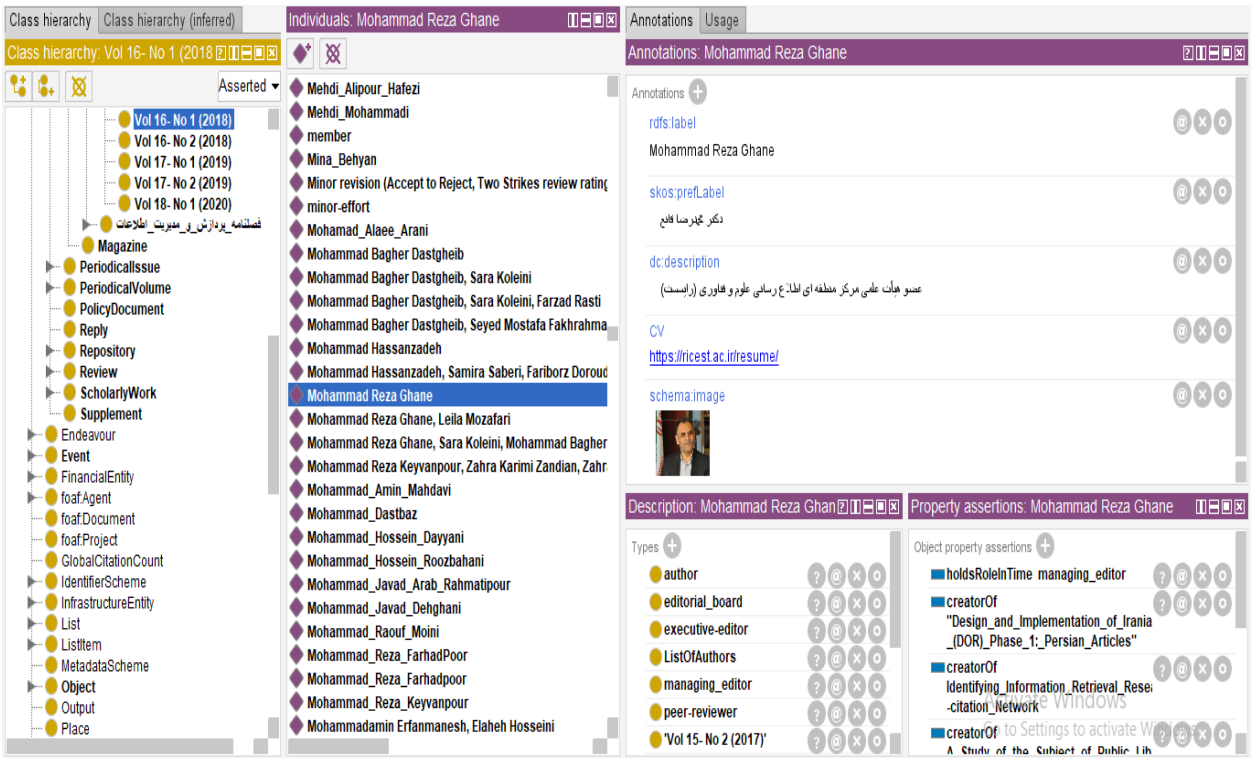

Figure 6: Describing Dr. Mohammad Reza Ghane in ISCOnt Ontology

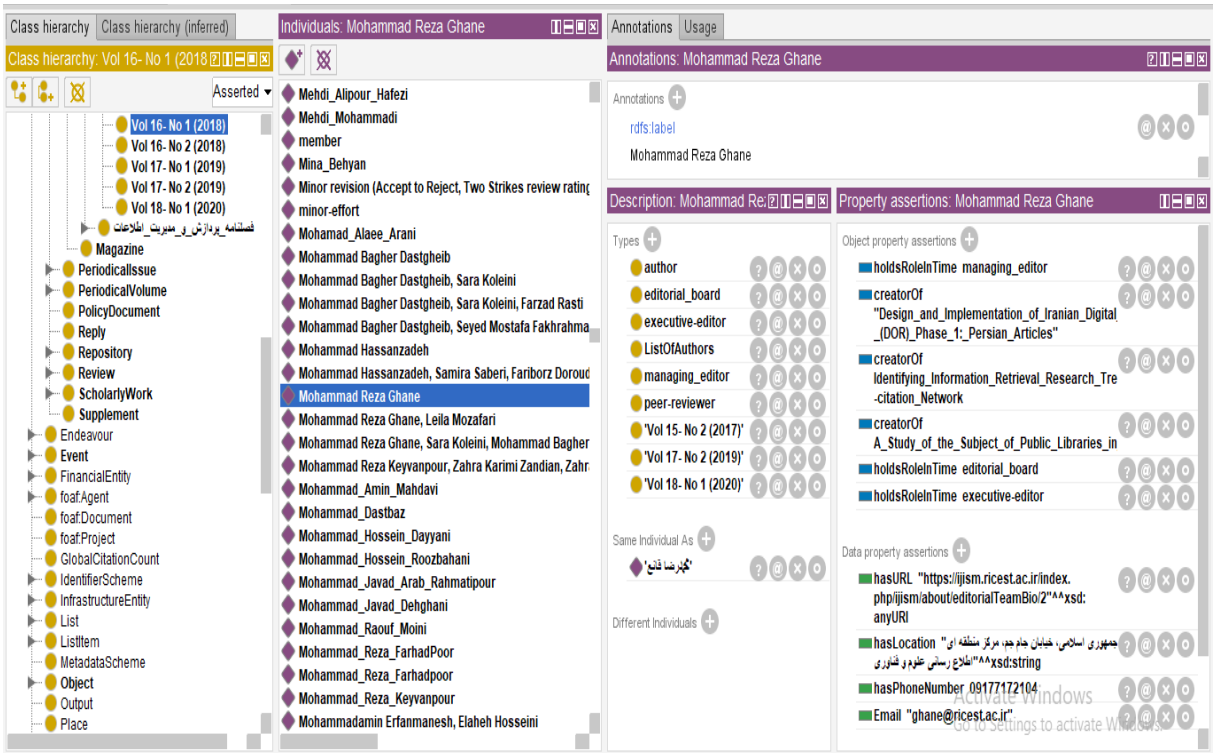

Figure 6: Describing Dr. Mohammad Reza Ghane in ISCOnt Ontology (continued)

Graphical representation of ISCOnt

After creating the ISCOnt ontology model in the three sections "Classes," "Properties," and "Individuals" in Protégé 5.5, its RDF graphs can be drawn. The OntoGraf and OWLViz plugins and the WebVOWL web application displayed the ISCOnt ontology

graphically. Figure 7 shows the RDF graph for Dr. Ghane.

These are the results of the RDF graph analysis in Figure 7:

A) Dr. Mohammad Reza Ghane, as a member of the editorial board of IJISM, also holds other roles such as author, reviewer, **Managing Editor,** and **Executive Editor** in this journal, and therefore, Dr. Ghane is an individual who belongs to several different classes.

B) Dr. Ghane has authored several articles on various issues of IJISM. Since in ISCOnt, a separate class is taken into account for each journal issue, as shown in Figure 7, the relations between Dr. Ghane and all classes of journal issues (e.g., "Volume 17-Number2 (2019)" etc. are created.

C) According to Figure 7, some of the authors who are members of the editorial board of IJISM also play the role of author or reviewer (e.g., Dr. Hamida Alizadeh, Dr. Farideh Osare, etc.). These relationships are specified in the RDF graph.

D) In the RDF graph, extending the classes is possible. In Figure 7, if we click on the class "Volume 17- Number2 (2019)", other entities associated with this class, e.g., articles, authors, etc., will be displayed (Figure 8).

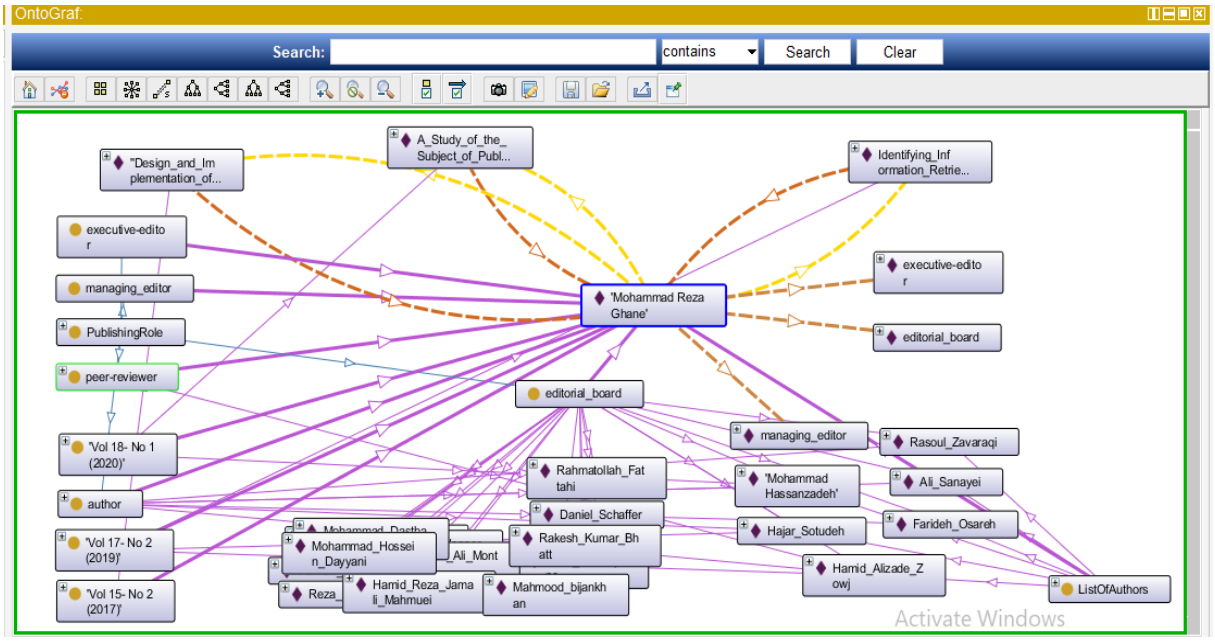

Figure 7: A Graphic View of the Class "Mohammad Reza Ghane" Drawn with the OntoGraf Plugin

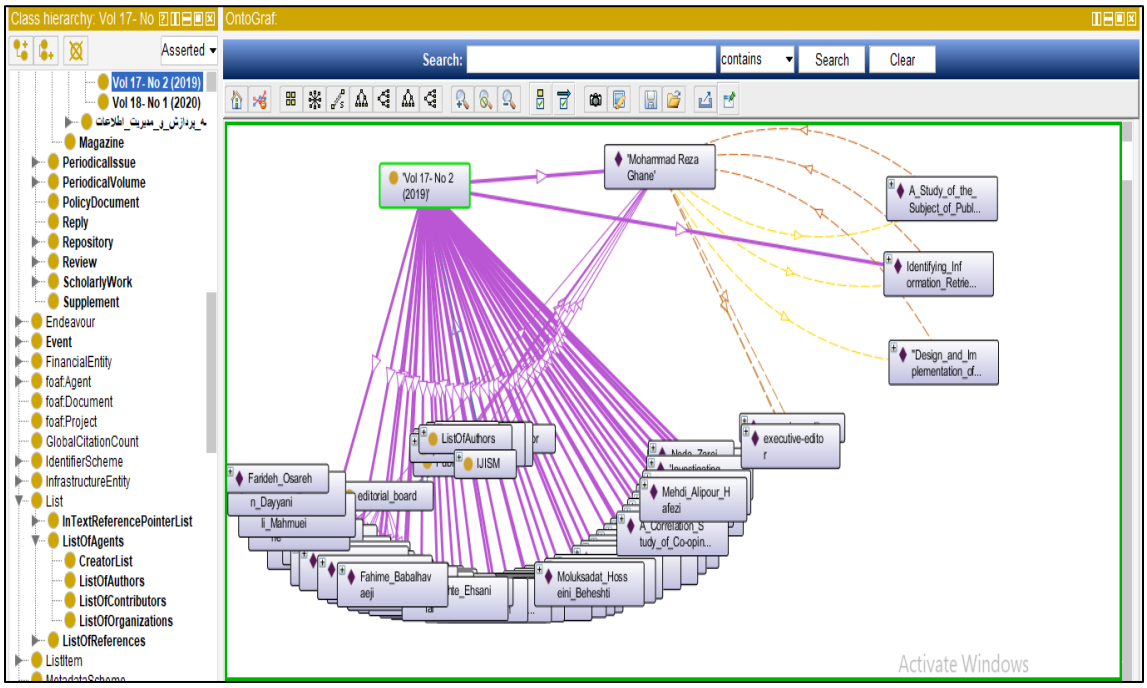

Figure 8: A graphic view of the Class "Volume 17- Number 2…" Drawn with the OntoGraf Plugin

One of the articles in this IJISM issue is "CivilOnto: An Ontology-Based on Persian Articles Published in Civil Engineering Domain," which has four authors. Figure 9 shows the description of this article in the ISCOnt ontology. The article's address and its full text in IJISM are shown in the Annotations window. The Description window displays the classes (types) this article belongs to (including Journal Article and Journal Issue). The Property Assertions window shows the object properties and data properties associated with this article, e.g., the creators, the scientific roles, the order of the authors' names, the abstract and keywords, etc.

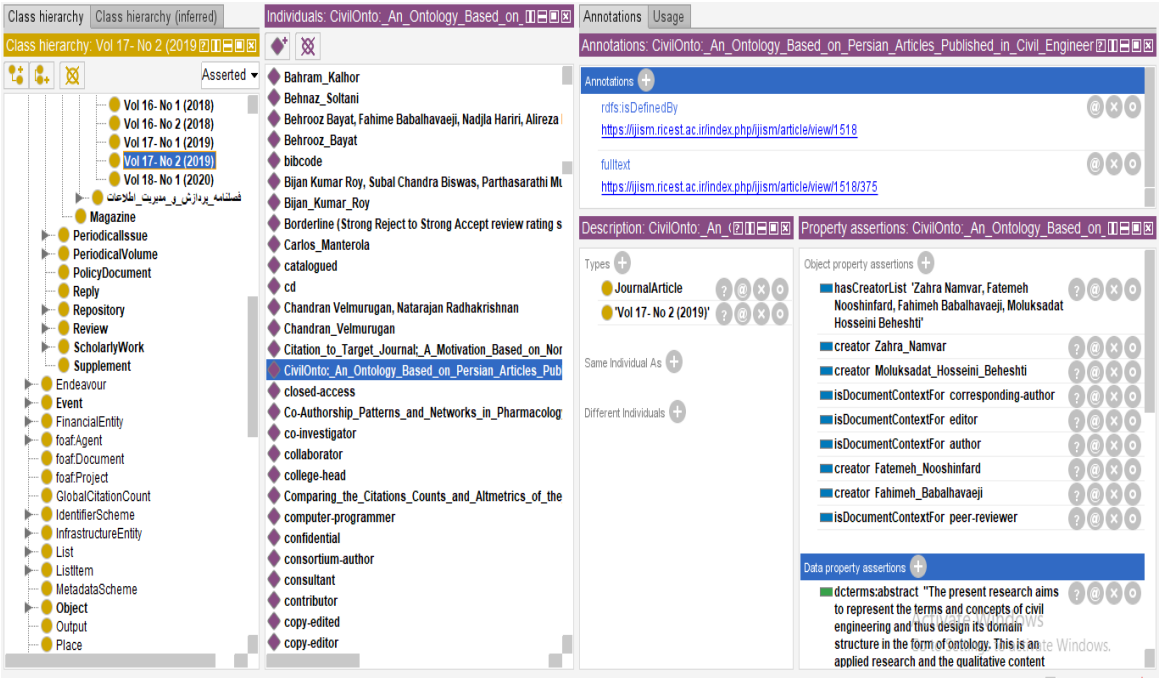

Figure 9: Describing the Article "CivilOnto: An Ontology-Based..." in ISCOnt Ontology

Figure 10 displays a graphic representation of the paper "CivilOnto: An Ontology-Based." According to Figure 10, each author has articles in other journals that can be tracked using RDF graphic vectors.

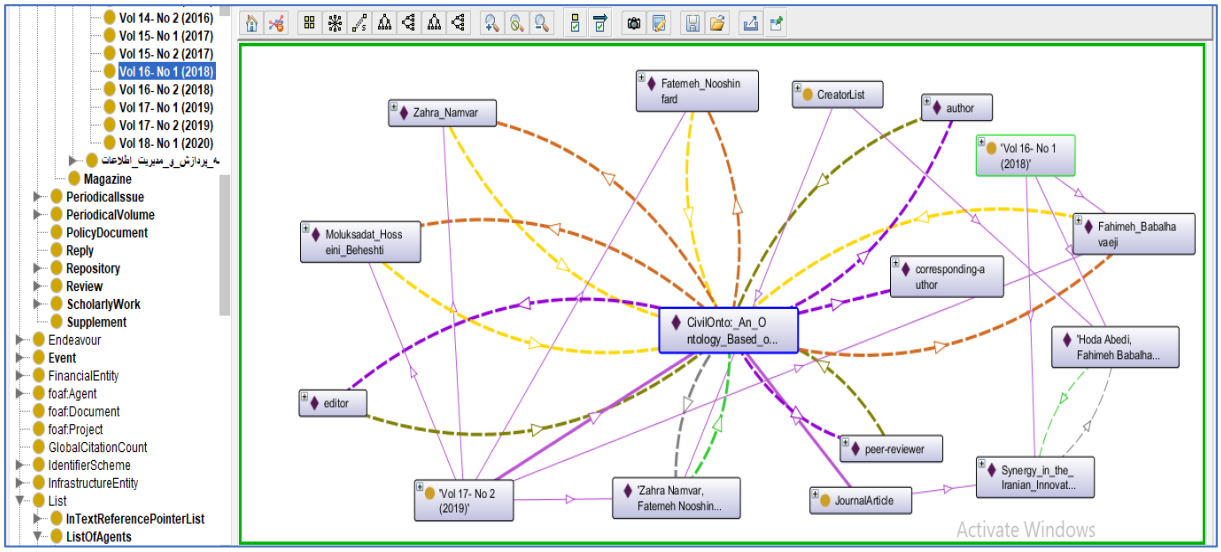

Figure 10: A Graphic View of the Article "CivilOnto: An Ontology-Based..." Drawn with the OntoGraf Plugin

In the ISCOnt ontology model, the PublishingStatus class displays the article's different publishing statuses (e.g., accepted, rejected, under review, unpublished, etc.). Figure 11 shows a graphic view of the Publishing Status class.

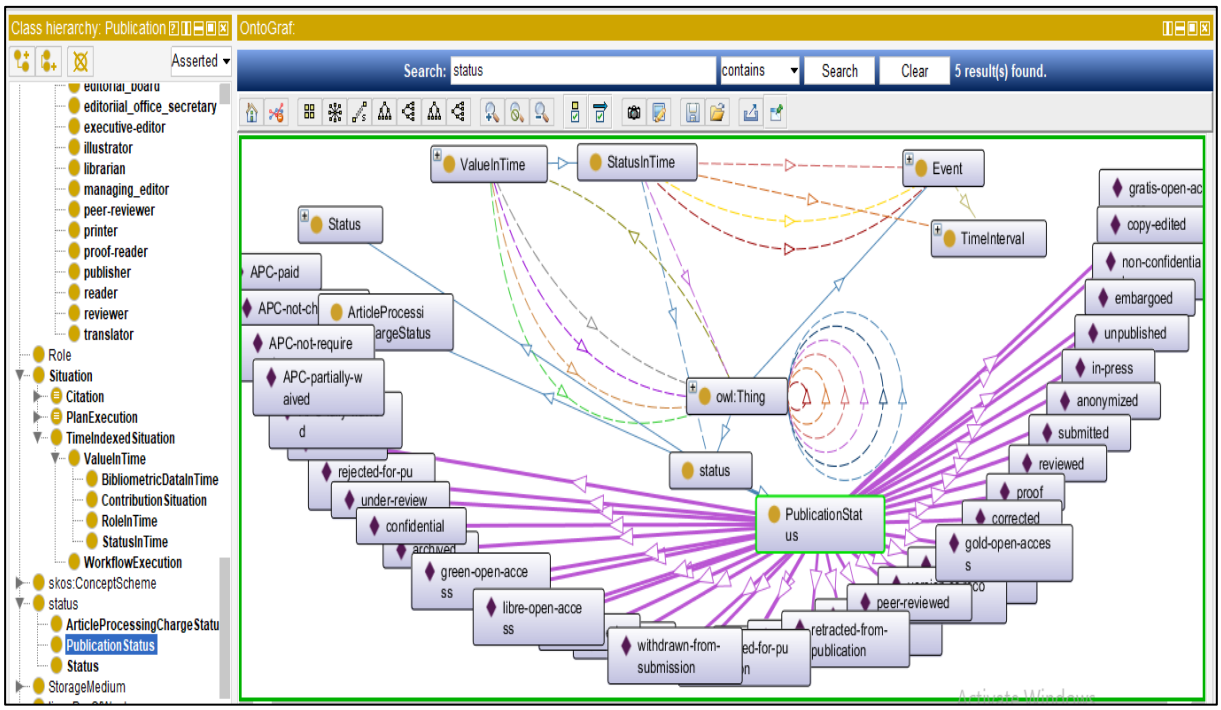

Figure 11: A Graphic View of the Publishing Status Class Drawn with the OntoGraf Plugin

Other plugins can display ISCOnt graphs in addition to the OntoGraf plugin. Figures 12 and 13 show the RDF graphs associated with the ISCOnt ontology created with the OWLViz plugin.

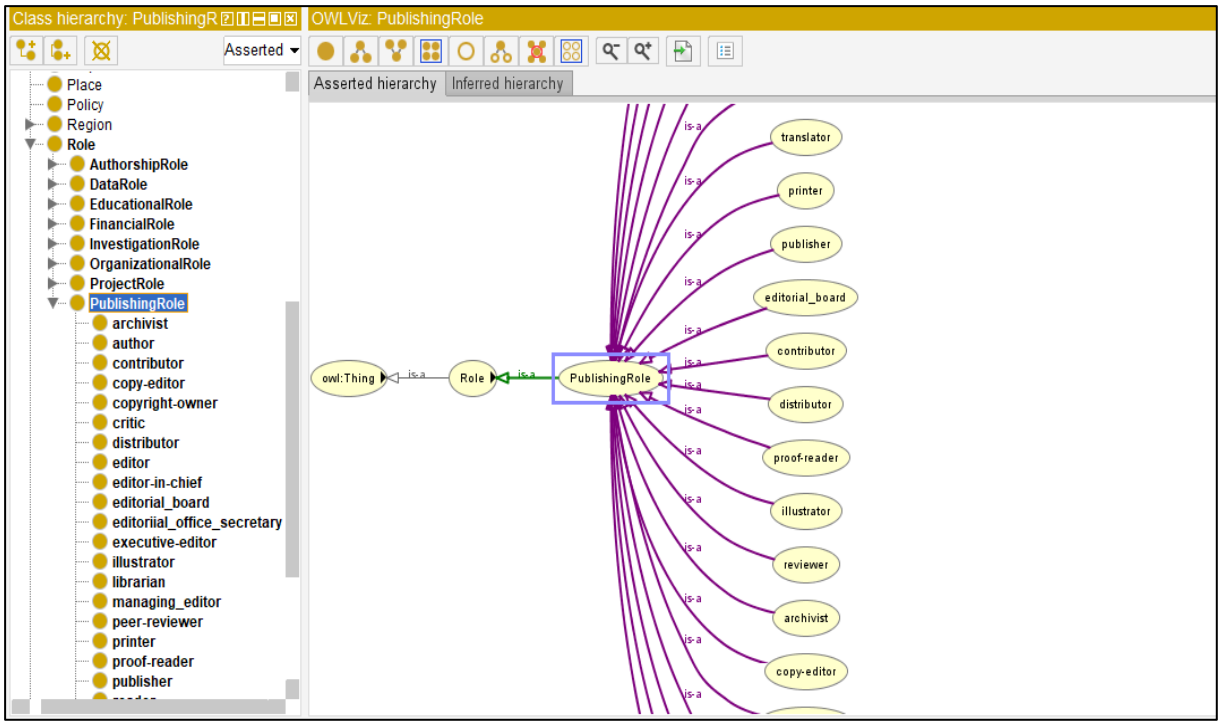

Figure 12: A Graphic View of the Publishing Status Class Drawn with the OWLViz Plugin

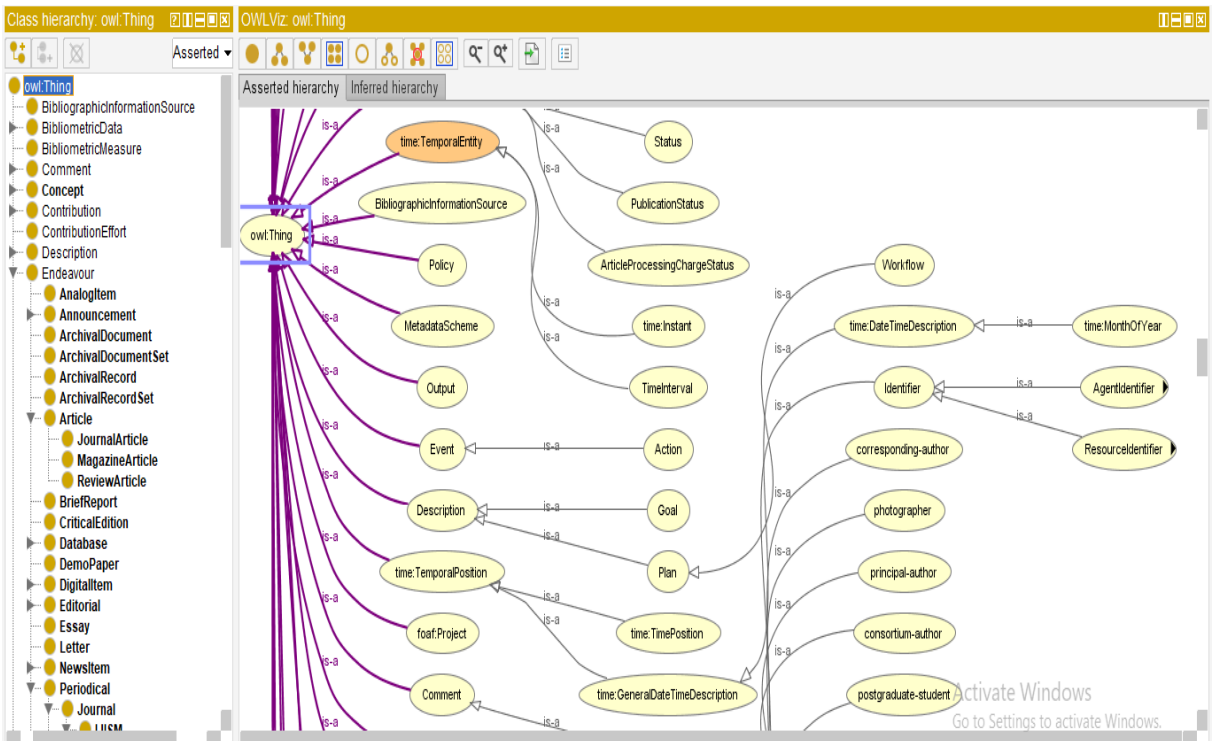

Figure 13: A Graphic View of the ISCOnt Ontology Drawn with the OWLViz Plugin

One of the web applications for interactive visualization of ontologies is WebVOWL,

which is used for online graphical representation of the ontology by importing its OWL file. This application was also used to display the ISCOnt ontology in this research. Figures 14 to 16 represent the RDF graphs of this ontology in WebVOWL.

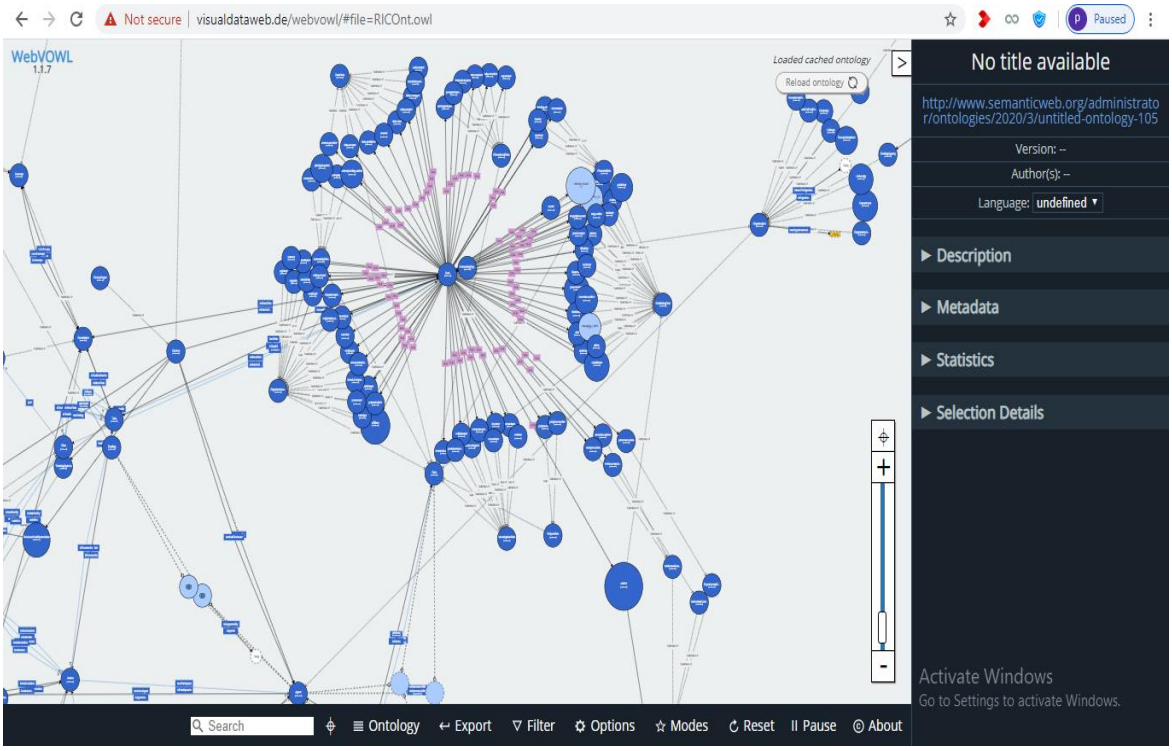

Figure 14: A Graphic View of the ISCOnt Ontology Drawn with the WebVOWL Application

When you click on the Journal Article class in Figure 14, its relationship to other courses is displayed in a different color. In Figure 15, these relationships are shown.

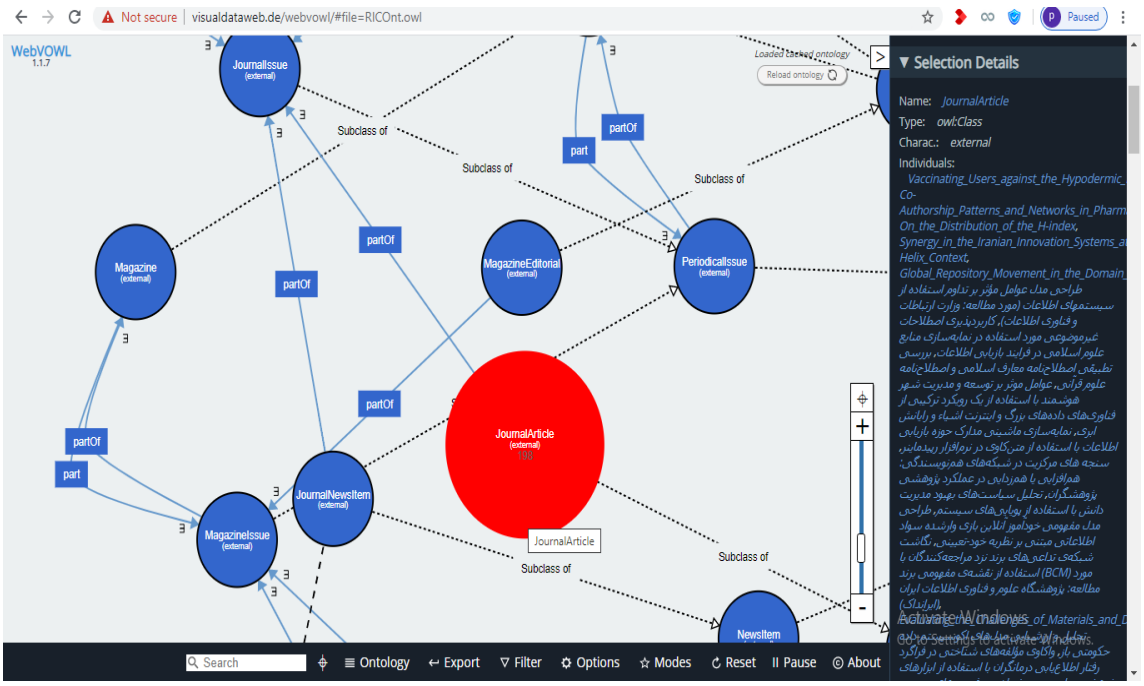

Figure 15: A Graphic View of the Journal Article Class Drawn with the WebVOWL Application

Figure 16 shows the graphical representation of the Publishing Role class.

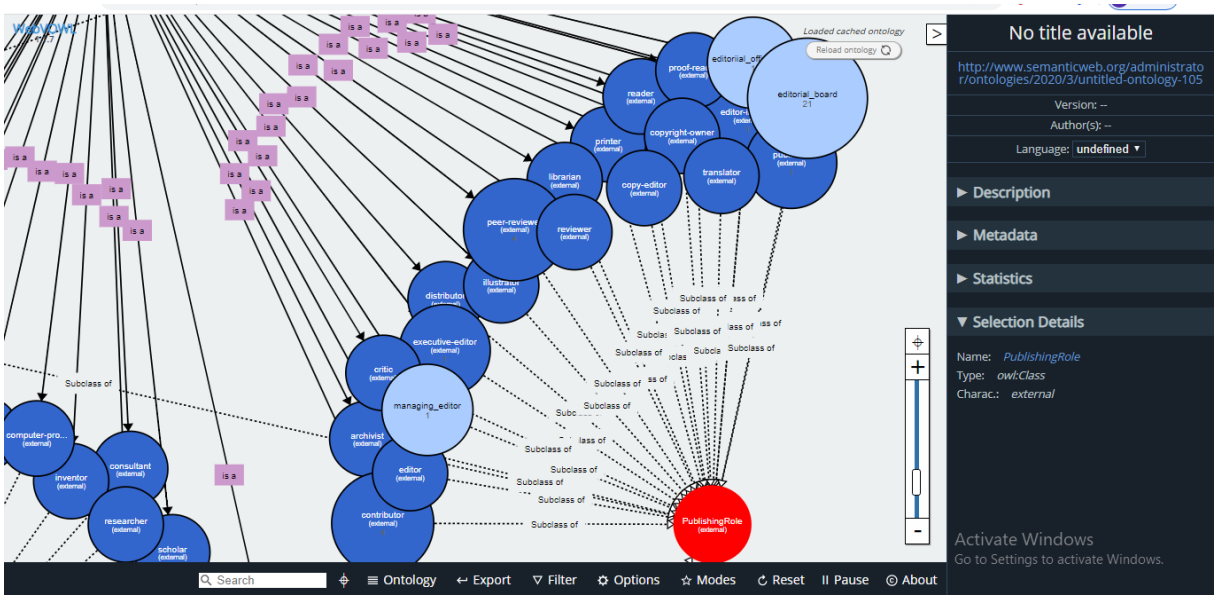

Figure 16: A Graphic View of the Publishing Role Class Drawn with the WebVOWL Application

Discussion

It can be concluded that displaying the classes and relationships graphically and drawing the RDF graphs using Protégé plugins allows the representation of metadata entities and the relationships between them clearly and understandably for ontology designers and Users. The ISCOnt ontology model makes it possible to show users more relationships between entities, which improves the ISCOnt's usability. The extensive use and development of SPAR ontologies in diverse research projects, as in this study, highlight the congruence of these studies in employing SPAR ontologies for semantic modeling. For instance, Shotton et al. (2009) semantically enriched a biomedical research article and published its machine-readable RDF metadata, developing the Citation Typing Ontology (CiTO). In line with this study, Bartalesi and Meghini (2015) and Daquino & Tomasi (2015) utilized the CiTO ontology model to describe the citations of scientific publications in ISCOnt ontology.

Peroni et al. (2012), by introducing the Live OWL Documentation Environment (LODE), used one of the SPAR ontologies, FaBiO (FRBR-aligned Bibliographic Ontology) to describe the bibliographic entities. Following this research, we adopted the FaBiO ontology to describe ISC scholarly journal articles. Moreover, similar to Osborne et al. (2014) and Tapia-León et al. (2019), we used Bibliometric Data Ontology and BiDO Standard Bibliometric Measures to describe metrics and statistical data of bibliographic resources in ISCOnt. Additionally, we used the Publishing Roles Ontology (PRO) to represent the publishing roles in ISCOnt ontology, similar to Daquino, Peronib, Tomasi, and Vitali (2014). In general, these studies depicted that by adopting semantic publishing practices, the metadata models in scholarly literature are enhanced by ontological representations. The SPAR Ontology Network is a complete set of ontologies that allows us to represent information about scholarly publishing and some measures of scientific production. It allows us to capture complex relationships between entities such as authors, publications, institutions, and topics. By leveraging the SPAR Ontology

Network, we were able to achieve a more precise and granular semantic representation of scholarly publications.

Conclusion

This study identified necessary metadata entities for semantic modeling and representation of ISC scholarly journal articles. A metadata ontology model was designed using Protege, and its RDF representation was created in RDF/XML syntax. Analyzing the RDF graph of the developed ontology model revealed the significance of its structure in improving the semantic description and representation of metadata entities in ISC scholarly journal articles. In conclusion, it is suggested that the ISC implement the ISCOnt metadata ontology model to represent the journal articles semantically and implement the linked data method, given the need to stay current with the latest journal organization and management advancements. It is also recommended that, in line with the new developments in information systems, the ISC seriously pursues converting its bibliographic metadata to the RDF model and publishing the journal data globally. Considering that the current study population includes articles published in ISC Persian and English scholarly journals, it is recommended that this research be conducted based on other types of ISC bibliographic resources (e.g. theses, reports, manuscripts, books, etc.). It is also suggested that the requirements for converting ISC metadata into an RDF data model and its conversion based on the linked data method are investigated in the research. One of the essential requirements for designing and implementing Semantic Web technologies in information retrieval systems is the standardization of these systems using conceptual models, metadata schema, and content standards such as RDA. Therefore, it is suggested that research be done on the standardization of ISC journal article metadata.

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