Concordia University

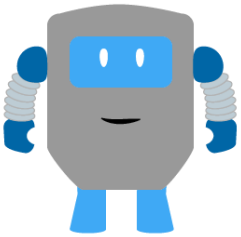
Engineering and Computer Science

COMP 6741

Intelligent Systems

Project-1 Report

Studybot



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1. Abstract

Students often have a lot of questions about courses, course topics, course materials and so on. To answer these questions, they often have to navigate through several webpages, or try to ask friends who have completed the same course. This project proposed a new "friend" referred as Studybot, which is an intelligent agent that can answer university-related questions using a knowledge graph and natural language processing.

In the first part of the project, we are going to focus on building the knowledge graph. Therefore, we are going to explore the approach to build the knowledge graph, the vocabularies used or extended.

Then we are going to write a series of competency questions which will ascertain that the knowledge graph can support these queries.

2. Knowledge base

2.1 Vocabulary

For this project, we explored some of the public vocabularies, including:

- RDF
- FOAF
- OWL
- Dublin Core
- VIVO
- BIBO
- EVENT
- SKOS

Most of the vocabularies and ontologies does not completely fit the requirements and they have to be extended or should use other vocabularies.

The VIVO vocabulary [5][6] provides a good and complete option, but for the sake of exploring, we decided to go with Dublin Core [3].

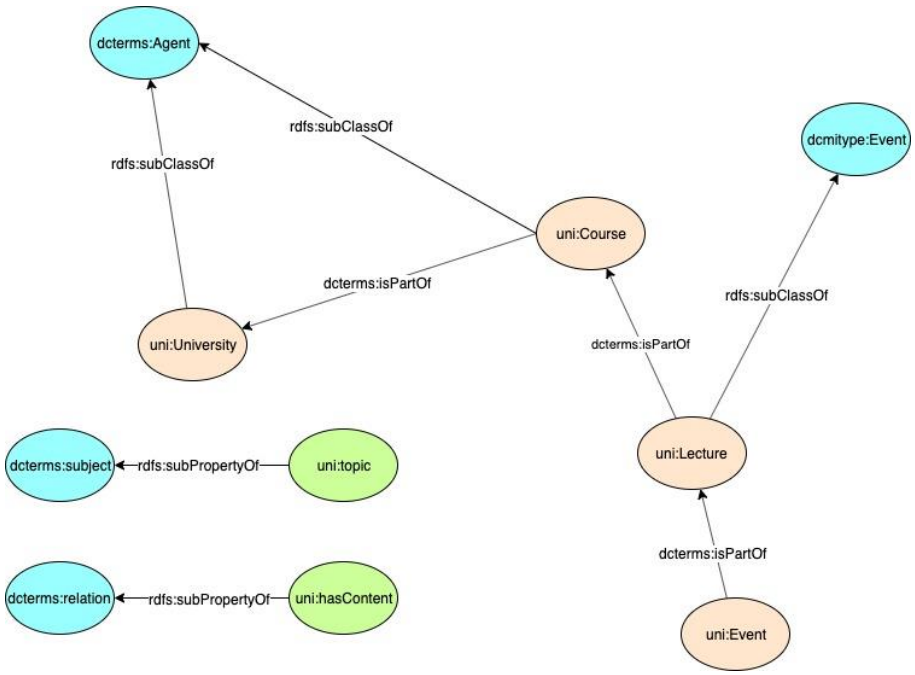
There are fifteen terms of the Dublin Core™ Metadata Element Set (also known as "the Dublin Core") plus several dozen properties, classes, datatypes, and vocabulary encoding schemes. The "Dublin Core" plus these extension vocabularies are collectively referred to as "DCMI metadata terms" ("Dublin Core terms" for short). These terms are intended to be used in combination with metadata terms from other, compatible vocabularies in the context of application profiles.

DCMI metadata terms are expressed in RDF vocabularies for use in Linked Data. Creators of non-RDF metadata can use the terms in contexts such as XML, JSON, UML, or relational databases by disregarding both the global identifier and the formal implications of the RDF-specific aspects of term definitions. Such users can take domain, range, sub property, and subclass relations as usage suggestions and focus on the natural-language text of definitions, usage notes, and examples.

The Dublin core provides a good basis for building out own vocabulary.

2.2 Schema

The diagram gives and overview of the main classes and properties extended from Dublin Core.



2.2.1 Prefixes

Prefix	URI	Comments
rdfs	<http://www.w3.org/2000/01/rdf-schema#>	
rdf	<http://www.w3.org/1999/02/22-rdf-syntax-ns#>	
xsd	<http://www.w3.org/2001/XMLSchema#>	
dbo	<http://www.dbpedia.org/ontology/>	
dbr	<http://www.dbpedia.org/resource/>	
dcterms	<http://purl.org/dc/terms/>	
dcmitype	<http://purl.org/dc/dcmitype/>	
dc	<http://purl.org/dc/elements/1.1/>	
uni	<http://uni.io/schema#>	

unidata	<http://uni.io/data#>	

2.2.2 Specifications

The following table provide the vocabulary that has been used in the schema

Vocabulary	Type of Term	Comments
rdf	rdf:type	Defines a type, used "a"
	rdf:Property	Defines a property
rdfs	rdfs:Class	Identifies a class
	rdfs:subClassOf	Identifies a sub class and the class from which it is sub classed
	rdfs:domain	Identifies the domain
	rdfs:range	Identifies the range
	rdfs:seeAlso	Provides a link to a related resource such as website
	rdfs:label	Provide a label
	rdfs:comment	Provides a description
dcterms	dcterms:Agent	A resource that acts, or has the power to act, in that case a University or Course
	dcterms:subject	A topic of the resource. Can use a URI or literal
	dcterms:relation	A related resource. Recommended to identify resource by a URI, but can use a string conforming formal identification
	dcterms:BibliographicResource	A bibliographic resource, for example a book, article or other documentary resource
dcmitype	dcmitype:Event	A class that is non-persistent, time based occurrence

2.2.3 Class Modeling

This section provides a description of the different terms used in the schema and for building the data components

University: Class

University is defined as a Class, and extends the Agent class from Dublin Core. The University is the primary agent that has the power to act

Schema	Data example
uni:University a rdfs:Class ; rdfs:subClassOf dcterms:Agent ; rdfs:label "University"@en ; rdfs:comment "University information" .	unidata:Concordia_University a uni:University ; dcterms:title "Concordia University"@en ; rdfs:seeAlso dbr:Concordia_University .

Course: Class

Course is defined as a Class, and extends the Agent class from Dublin Core. The class is an agent that has the power to act. The following terms are also used:

Schema	Data example
uni:Course a rdfs:Class ; rdfs:subClassOf dcterms:Agent ; rdfs:label "Course"@en ; rdfs:comment "Courses offered at University"@en .	unidata:COMP6741 a uni:Course ; dcterms:title "Intelligent Systems"@en ; dcmitype:subject "COMP" ; dcmitype:identifier "6741"; dcterms:description "Knowledge representation"@en ; rdfs:seeAlso <https://moodle.concordia.ca> ;

	uni:topic dbr:Intelligent_Systems ; dcterms:isPartOf unidata:Concordia_University ; uni:hasContent unidata:Doc1 .
Terms associated with Course:	
dcterms:title	Identifies the name of the course
dcmitype:subject	Identifies subject of course, e.g. COMP, SOEN
dcmitype:identifier	Identifies the number of the course, e.g 6741
dcterms:description	Provides a description of the course
rdfs:seeAlso	Link to webpage with the course information
uni:topic	Identifies topic of course, linked to DBpedia
dcterms:isPartOf	Identifies the University which course belongs to
uni:hasContent	Content, mainly the course outline

Lecture: Class A lecture is an event that belongs to a course. Lecture extens the event class from Dublin Core as it is a non-persistent time base occurence	
Schema	Data example
uni:Lecture a rdfs:Class ; rdfs:subClassOf dcmitype:Event ; rdfs:label "Lecture"@en ; rdfs:comment "Information about lecture"@en .	unidata:COMP6741L01 a uni:Lecture ; dcmitype:identifier "1"; dcterms:title "Introduction to Intelligent S."@en ; rdfs:seeAlso <https://moodle.concordia.ca> ; uni:topic dbr:Intelligent_Systems ; uni:hasContent unidata:Doc02 ; dcterms:isPartOf unidata:COMP6741 .
Terms associated with Lecture:	
dcmitype:identifier	Identifies lectures number
dcterms:title	Identifies the lecture name
rdfs:seeAlso	Link to webpage with the lecture information
uni:topic	Identifies topic of a lecture, linked to DBpedia
dcterms:isPartOf	Identifies the course to which lecture belongs to
uni:hasContent	Content, any documents that is associated with lecture such as slides, worksheets, etc

Event: Class An event extends a lecture as it is associated with the lecture and is also time based. It can be any event associated with a lecture, such as a tutorial or lab	
Schema	Data example
uni:Event a rdfs:Class ; rdfs:subClassOf uni:Lecture ; rdfs:label "Lecture Event"@en ; rdfs:comment "Events associated with a Lecture such as Lab ror Tutorial"@en .	unidata:L674101 a uni:Event ; dcterms:type "LAB" ; uni:isPartOf unidata:COMP6741L01 ; uni:topic dbr:Python .
Terms associated with Event:	
dcterms:type	Identifies type of event, can be lab, tutorial or some other event
dcterms:isPartOf	Identifies the lecture to which event belongs to
uni:hasContent	Identifies content specific to that lab
uni:topic	Identifies topic of lab, linked to DBpedia

2.2.4 Property Modeling

topic: Property
A topic is a sub property of subject, which identifies a link to DBpedia

Schema	Data example
uni:topic a rdf:property ; rdfs:subPropertyOf dcterms:subject ; rdfs:label "Topic"@en ; rdfs:comment "URI"@en .	unidata:L674101 a uni:Event ; dcterms:type "LAB" ; uni:isPartOf unidata:COMP6741L01 ; uni:topic dbr:Python .

hasContent: Property
Identifies the contents that are associated with a course, lecture or event

Schema	Data example
uni:hasContent a rdf:property ; rdfs:subClassOf dcterms:relation ; rdfs:label "Content"@en ; rdfs:range dcterms:BibliographicResource rdfs:comment "Content associated with a course, lecture"@en .	unidata:COMP6741L01 a uni:Lecture ; dcmitype:identifier "1"; dcterms:title "Introduction to Intelligent Systems"@en ; rdfs:seeAlso <https://moodle.concordia.ca> ; uni:topic dbr:Intelligent_Systems ; uni:hasContent unidata:Doc02 ; dcterms:isPartOf unidata:COMP6741 .

The content itself is not described as part of the schema. The content is a BibliographicResource defined as follows:

```
unidata:Doc06
   a dcterms:BibliographicResource ;
   dcterms:type "LECTURE" ;
   dcterms:source /University/COMP6741/slides03.pdf> .
```

dcterms:type	Identifies the type of content, e.g. OTHER, SLIDES, WORKSHEET
dcterms:source	Locates the resource

3. Data extraction

The data was extracted from the https://opendata.concordia.ca/datasets/. The following files were used to create the .csv files we require for the project:

- CU_SR_OPEN_DATA_CATALOG-37296852.csv (To get Course ID, Subject, Number, Title)
- CU_SR_OPEN_DATA_CATALOG_DESC.csv (To get Course Description)
- CATALOG.csv and Experiential Learning.csv (To get Course Website/seeAlso)

The required files for project were generated by doing some work manually like extracting required columns from, removing duplicates, adding seeAlso data, data for two courses and other work like merging 2 .csv files based on common column value is done using small python script: data.py.

```
import pandas as pd

data1 = pd.read_csv("Data.csv",encoding= 'latin1')
data2 = pd.read_csv("DES.csv",encoding= 'latin1')
#merge function by setting how='left'
output = pd.merge(data1, data2, on='Course ID', how='left')
output.to_csv("output.csv")
```

```
data3 = pd.read_csv("output.csv",encoding= 'latin1')
data4 = pd.read_csv("WEBSITE.csv",encoding= 'latin1')
output1 = pd.merge(data3, data4, on='Course ID', how='left')
output1.to_csv("course.csv")
```

data.py

The following files are generated and used for creating Knowledge Graph:

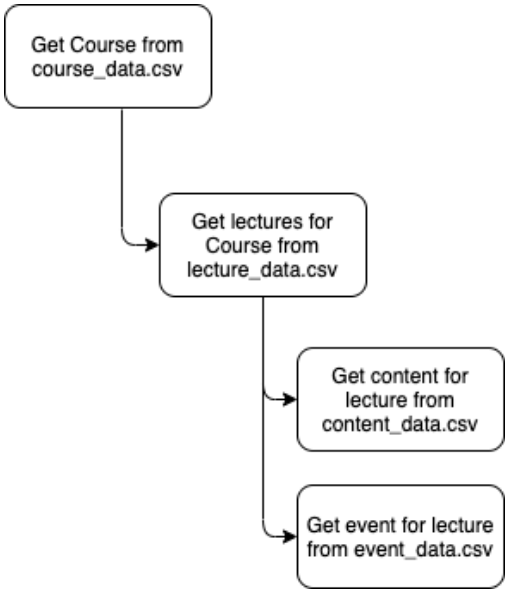
1. course_data.csv: contains all the courses and descriptions extracted from opendata.concordia.
2. lecture_data.csv: contains the lectures information for 2 courses that were manually updated.
3. event_data.csv: contains the lab events information for 2 courses that were manually updated.
4. content_data.csv: contains the content information for 2 courses that were manually updated.

4. Knowledge base

The building of the knowledge base uses python programming language and the following librairies:

1. pandas – for reading the .csv data files
2. uuid – for generating unique identifies for the resources
3. rdflib –
    a. Graph – for creating knowledge graph
    b. Namespace – to manage the namespace use and creation
    c. RDFS, RDF DC, DCTERMS – provided namespace in rdflib
    d. URIRef – for creating URI
    e. Literal – for adding literal vales, not URI

The following diagram give a general flow of the code structure.



- The university is added through the code to the graph

```
#Add Univeristy to graph
graph.add( (URIRef(UNIDATA.Concordia_University), RDF.type , UNI.University))
graph.add( (URIRef(UNIDATA.Concordia_University), DCTERMS.title , Literal("Concordia University", lang="en")))
graph.add( (URIRef(UNIDATA.Concordia_University), RDFS.seeAlso, DBR.Concordia_University))
```

- For each line in the course file, the information for the course is read, and inserted into the graph. The ID of the course is obtained from the course_data.csv file

```
for courseline in range(len(course_data)):
    course = course_data.iloc[courseline]

    courseId = UNIDATA[str(course['CourseId'])]
    graph.add((courseId, RDF.type, UNI.Course))
....
```

- For each course, the lecture for the course and information of lectures are inserted in graph
The ID of the lecture is a unique Id generated. Given temporal existence of lecture.

```
            #For each course, add lectures
                courseLectures = lecture_data[lecture_data['CourseId'] == course['CourseId']]
                for lectureline in range(len(courseLectures)):
                    lecture = courseLectures.iloc[lectureline]
                    lectureId = UNIDATA["l" + str(uuid4())]
                    graph.add((lectureId, RDF.type, UNI.Lecture))
            ...
```

- For each lecture, the events (lab or tutorial) and the contents of the lecture are inserted in the graph

```
                #Content associated withe a lecture
            lectureContents = content_data[(content_data['CourseId'] == course['CourseId']) & (content_data['Identifier'] ==
            lecture['Identifier'])]
                for contentline in range(len(lectureContents)):
                    content = lectureContents.iloc[contentline]
            ....
      #Events (labs/tutorials) associated with a lecture
       lectureEvents = event_data[(event_data['CourseId'] == course['CourseId']) & (event_data['Identifier'] ==
lecture['Identifier'])]
       for eventline in range(len(lectureEvents)):
           event = lectureEvents.iloc[eventline]
           eventId = UNIDATA["e" + str(uuid4())]
```

- Content creation. A unique ID is created for each content
Local content should be place in the fuseki server in the /webapp folder. The namespace LOCAL was used in the code

```
            def add_documents(location, type):
           contenId = UNIDATA["c" + str(uuid4())]
                graph.add((contenId, RDF.type, DCTERMS.BibliographicResource))
                graph.add((contenId, DCTERMS.type, Literal(type)))
                graph.add((contenId, DCTERMS.source, URIRef(location)))
                return contenId
```

5. Queries

The following queries have been used to test the graph. The queries can be found in the accompanying queries.sparql file. In the report, we will limit to 10 queries, but more are defined in the queries.sparql file

```
# Question 1
# What is the course [title] and [description] of [subject] [number]?
# What is the course title and description of COMP 6741?
SELECT ?title ?descr
WHERE {
   ?course dcmitype:subject "COMP" .
   ?course dcmitype:identifier "6741" .
   ?course dcterms:title ?title .
   ?course dcterms:description ?descr
}

# Question 2
# Which topics are covered in [subject] [number] lectures?
# Which topics are covered in [COMP] [6741] lectures?
SELECT ?course ?lecture ?topic
WHERE {
   ?course1 dcmitype:subject "COMP" .
   ?course1 dcmitype:identifier "6741" .
   ?course1 dcterms:title ?course .
   ?lecture1 dcterms:isPartOf ?course1 .
   ?lecture1 dcmitype:identifier ?lecture .
   ?lecture1 uni:topic ?topic
} ORDER BY ?lecture

# Question 3
# Which lecture of [subject][number] covers [topic]?
# Which lecture of [COMP][6741] covers [Knowledge_grap]?
SELECT ?number
WHERE {
   ?course dcmitype:subject "COMP" .
   ?course dcmitype:identifier "6741" .
   ?lecture dcterms:isPartOf ?course .
   ?lecture uni:topic dbr:Knowledge_Graph .
   ?lecture dcmitype:identifier ?number
}

# Question 4
# How many courses are offered at Concordia University?
SELECT (count(?courseId) as ?CourseCount)
WHERE{
   ?courseId rdf:type uni:Course
}

# Question 5
# What are the recommended reading materials for [subject][number] by lecture?
# What are the recommended reading materials for [COMP][6741] by lecture?
SELECT ?number ?source
WHERE {
   ?course dcmitype:subject "COMP" .
   ?course dcmitype:identifier "6741" .
   ?lecture uni:hasContent ?content .
   ?lecture dcterms:isPartOf ?course .
   ?lecture dcmitype:identifier ?number .
   ?content dcterms:type "READING" .
   ?content dcterms:source ?source .
} order by ?number
```

Question 6
What are the contents in [subject][number] for each lecture?
What are all the contents for COMP 6741 for each lecture?

```
SELECT ?number ?content_type ?source
WHERE {
   ?course dcmitype:subject "COMP" .
   ?course dcmitype:identifier "6741" .
   ?lecture uni:hasContent ?content .
   ?lecture dcterms:isPartOf ?course .
   ?lecture dcmitype:identifier ?number .
   ?content dcterms:type ?content_type .
   ?content dcterms:source ?source .
} order by ?number
```

Question 7
Does [subject][number] and [subject][number] cover similar topic?
Does COMP 6741 and comp 6721 cover similar topic?

```
ASK
{
   ?course1 dcmitype:subject "COMP" .
   ?course1 dcmitype:identifier "6741" .
   ?course1 uni:topic ?topic1 .
   ?lecture1 dcterms:isPartOf ?course1 .
   ?lecture1  uni:topic ?topic3 .
   ?course2 dcmitype:subject "COMP" .
   ?course2 dcmitype:identifier "6721" .
   ?course2 uni:topic ?topic2 .
   ?lecture2 dcterms:isPartOf ?course2 .
   ?lecture1  uni:topic ?topic4 .
   FILTER(?topic1 = ?topic2 || ?topic3 = ?topic4 ) .
}
```

#Question 8
What is the outline for [Subject] [number] ?
What is the outline for COMP 6741 ?

```
SELECT  ?outline
WHERE {
   ?course rdf:type uni:Course .
   ?course dcmitype:subject "COMP" .
   ?course dcmitype:identifier "6741" .
   ?course uni:hasContent ?content .
   ?content dcterms:type "OUTLINE" .
   ?content dcterms:source ?outline .
}
```

Question 9
Which courses cover [topic]?
Which courses cover [Machine_learning]?

```
SELECT (concat(?subject, " ", ?number) AS ?courseName)
WHERE {
   ?course dcmitype:subject ?subject .
   ?course dcmitype:identifier ?number .
   ?lecture dcterms:isPartOf ?course .
   ?lecture uni:topic dbr:Machine_learning .
}
```

```
# Question 10
# Does [subject][number] has [event]?
# Does [COMP][6841] has [LAB]?
ASK{
   ?course dcmitype:subject "COMP" .
   ?course dcmitype:identifier "6741" .
   ?lecture dcterms:isPartOf ?course .
   ?event dcterms:isPartOf ?lecture .
   ?event dcterms:type "LAB".
}
```

6. Statistics

Statistics	Count
Number of triples	51759
Number of courses	7259
Number of lectures	26
Number of events	26
Number of contents	138

7. Running program

1) Ensure rdflib, and pandas are installed in python environment
2) Place the university folder on the Fuseki server /webapp folder
3) Run the kbuilder.py
4) Run the Fuseki server and create a new dataset uni and upload Knowdlegde_base.nt
5) From the Queries.sparql file, copy with PREFIX section, copy the query that should be executed

8. References

[1] RDF Schema 1.1
https://www.w3.org/TR/rdf-schema/

[2] FOAF Vocabulary
http://xmlns.com/foaf/spec/

[3] Dublin Core Metadata Initiative
https://www.dublincore.org/specifications/dublin-core/dcmi-terms/#http://purl.org/dc/dcmitype/Event

[4] Vivo Core Ontology
https://lov.linkeddata.es/dataset/lov/vocabs/vivo

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https://info.sice.indiana.edu/~dingying/Teaching/S604/VIVO-tutorial-v1.pdf

[6] Merge 2 CSV files.
https://www.geeksforgeeks.org/how-to-merge-two-csv-files-by-specific-column-using-pandas-in-python/

[7] Write SPARQL query in Fuseki-Server
https://www.youtube.com/watch?v=5-UfFV5XmTI