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Towards Ontology-Based Academic Programmes Regulations Enforcement

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Key words: Regulations ontology, academic programme requirements ontology, academic regulations ontology, course regulations ontology, regulations enforcement

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Abstract: Academic programmes regulations play an important role in the quality of graduates produced by learning institutions. Development and enforcement of these regulations by the institutions can be error-prone due to the volumes of the regulations, complexity of the regulations and non-homogenious academic journeys by the students. In this study, an ontology of academic programmes regulations is proposed. The ontology is designed to model the academic regulations domain knowledge and is intended to provide support in the reference, development and enforcement of the regulations. An ontology of academic regulations fora case institution was developed. The ontology was based on the Curriculum Course Syllabus Ontology (CCSO). Preliminary assessment demonstrate that the academic programmes regulations ontology (APROnt) could support the processes of reference, development, revision and enforcement of the regulations.

INTRODUCTION

Growth of academic programmes offered in institutions of learning means inevitable growth in the volumes academic regulations that must be enforced. These regulations often vary from programme to programme and span the entire engagement period from the time one is a prospective student to the conclusion of the programme. Enforcing regulations of many programmes across a large volume of students is a demanding task. Another dynamic that further complicates enforcement of program regulations is the emerging trend of almost every student having a unique learning journey and not belonging to a nearly homogenious cohort throughout the period of study. Enforcing of regulations under the circumstance described above can be a daunting task, especially where the enforcement mostly relies on human knowledge on the regulations and se-mi automated processes.

Over the years, the use of ontologies to model domain knowledge and provide harmonised understanding among stakeholders in the domain and to enable automated support in the utilization of the knowledge has been explored. The education domain has been studied as well resulting in different ontologies and conceptual models to guide knowledge representation in the domain.

This study presents outcomes of modelling academic programmes regulations knowledge for purposes of providing support in the enforcement of the regulations. The research uses a case of the University of Nairobi, Kenya. The research studied the nature of regulations and sought to establish how the regulations could be modelled in an ontology for purposes of supporting their enforcement at various stages.

Ontology: An ontology is "a formal, explicit specification of a shared conceptualization"[1] where formal means the

specifications are encoded in logic-based language; explicit specification means concepts are given unambiguous names and definitions, shared means different groups that subscribe to the conceptualization can share and re-use the knowledge in the ontology; conceptualization means the way people perceive things in a given domain. Guarino *et al*.[2] defined an ontology as something used to embody the structure of a system.

These definitions imply that the knowledge captured in the ontology is available for interpretation both by humans and machines and therefore, machines can help make interpretations from the represented knowledge. This possibility is what renders ontologies appropriate for representing knowledge, so that, machines can help humans in accessing knowledge tailored to a specific need.

Regulations ontologies: The use on ontologies to represent knowledge on regulations is not a new concept. The use of ontologies to model regulations has been explored in different areas including legal regulations, road traffic regulations, building and construction regulations and environmental regulations among others. By Buechel *et al*.[3], traffic regulations are modelled in an ontology that provides support in computation of situational awareness for automated vehicles. The use of ontology makes it possible to support varying traffic rules from different countries in the automated vehicle thus enabling the vehicle to function in different regions. By Zhou and El-Gohary[4] an ontology is used to capture dependency information thus reduce text ambiguity in the support enforcement of environmental regulations documented in different repositories of the regulations. Faron-Zucker, etc., explored the use of ontology in the enforcement of building regulations by formalizing the regulations into an ontology which is then incorporated into conformance checking of models. Other research that used ontologies to model regulations includes the web-based legal advice system CLIME ontology[5], E-commerce privacy regulations ontology[6] and SSN ontology for classification of different water bodies based on regulations from different regulatory bodies. In these works, the role of the ontologies in supporting access to correct regulation and speedy access to the regulation is demonstrated. Regulations are also complex and relying on humans alone to sufficiently apply them is prone to errors and subjective enforcement.

Academic domain ontologies: The use of ontologies in representation of concepts in the academic domain has been explored in different dimensions. Boyce and Pahl[7] proposed a method for domain experts to create ontologies to guide development of instructional material for different courses. Zeng *et al*.[8] proposed a participative approach by non-professional users in the construction of a university ontology that encompass the course content, method and process. El-Ghalayini[9] created an ontology of E-learning concepts for supporting the development of E-learning courses. Ontology defines important domain concepts thereby supporting common understanding among stakeholders and applications.

Other research that looked at the academic domain ontologies includes Urakawa *et al*.[10] which proposes an ontology-based dynamic learning path framework for incorporation into a school learning system in Japan. The system is based on a curriculum ontology, of the course syllabus, that enables users to dynamically navigate through a learning path. Alomari proposed an ontology for academic programme accreditation to support institutions in the comparison of learning outcomes of different programmes offered by the involved institutions. Sabri[11] present a design for an integrated learning ontology encompassing the multi-level knowledge structures including courses, curriculum, syllabus and learning material. They propose a sematic model, of the syllabus which supports adaptive learning. Katis *et al*.[12] present an education knowledge structure in an academic setting. They present a re-usable ontology that can be applied to different institutions to model institutional knowledge relating to study programmes, courses, syllabus, curriculum tasks, staff and learning materials.

Need for an academic programmes regulations ontology: Academic programmes regulations like all other regulations are to a good extent structured and detailed enough to provide the necessary framework for the implementation of the programmes. An institution usually has general regulations that apply to all programmes and then more specific regulations that apply to each programme. Further regulations are often also defined for the courses and other activities undertaken under the programme.

Nature of knowledge: The academic programme regulations document all rules and conditions that must be met in order for the candidate to be awarded the qualification. The academic programmes regulations document the minimum entry requirements of a candidate in order to join the programme; the programme structure of what will be done at different stages; the learning requirements that must be fulfilled at each stage; the rules for transition from one stage to another; the applicable grading system at the different stages and the final grading system.

A check at the programmes offered by the case institution was found to have different sections in the academic regulations including:

- Programme code
- Programme name
- Philosophy of the programme
- Rationale of the programme
- Goal of the programme
- Mode of delivery (face-to-face, E-learning, blended, practice)
- Entry requirements
- Programme level whether it is certificate, diploma, degree, masters, fellowships PhD and postdoc
- Programme goals and expected outcomes
- Exceptions and credit transfer regulations
- Grading system
- Courses for each level
- Structure of each course including name, hours, description, reference materials
- Weight of each course
- Prerequisites of a unit where relevant
- Minimum duration and maximum duration
- Description of each course
- Learning outcomes of each course unit
- Reference material for each unit
- Programme status if still being offered, retired or upcoming
- Applicable penalties for any violations of the different parts of the regulation

Evolution of the knowledge: The academic regulations knowledge evolve over the years due to several reasons key among them being evolving industry needs, the need to in-coporate new knowledge that comes from research and the need to fill aparent gaps that have been identified over time. Most institutions have therefore put in place measures to ensure the regulations are reviewed on a minimum after every cycle of a programme. This means that for a four year programme, the regulations are reviewed every four years. This means that students who take the same academic programme in different years do not necessarily have the same regulations.

On the surface, the evolution of programme regulations may seem an obvious matter but the administrative overheads it introduces can be colossal. For instance, processing results for different cohorts of students taking the same course but with varying regulations (due to revisions) is not obvious; responding to queries from other institutions on programme structure covered by former students is difficult to keep track with changing regulations. It is therefore important to be able to retrieve and apply the correct regulation for the set of students the regulation is applicable to. It is also important to support the enforcement of the regulations review calendar and to monitor the changes.

Use of the regulations: The programme regulations guide many activities in academic institutions. The regulations are often used by prospective students and current students to guide them in the requirements for the qualifications they target or enrolled in respectively. These regulations are often enforced by the faculty and administrative staff responsible for the management of these programmes. The enforcement is mostly done with the help of database systems that have been created to manage student records and to support the enforcement process. The use of the regulations by the stakeholders is prone to inefficiencies and errors due to several factors:

- The inefficiency due to the need to make manual reference to the relevant documentation
- Reliance on the enforcement staff's knowledge on the regulations
- The risk of implementing different interpretations for different candidates
- The weakness of database technologies in the representation of the academic regulations knowledge

Modelling the academic programme regulations knowledge in an ontology makes it possible for machines and humans to have a common understanding and interpretation of the knowledge represented in it. The ontology can be used to provide automated support to the administrative processes using the knowledge represented in the ontology.

MATERIALS AND METHODS

Several methodologies for ontology development have been proposed and documented in literature. Some methodologies emerged from ontology development experiences such as TOVE methodology[13]. In the early 2000, tool-based methodologies emerged. These are methodologies that were developed based on ontology development tools such as the methodologies developed for Protégé[14, 15]. A methodology developed independent of ontology development project experience and tools but in reference to software development methodologies also exist in literature, the Software Centric Innovative Methodology (SCIM)[16].

This research adopted a combination of guidelines from two methodologies; the methodology proposed by Noy and McGuinness[15] and that of Horridge *et al*.[14]. The methodologies were adapted into coarse steps of defining the scope of the ontology, search of existing ontologies for reuse, ontology modelling and evaluation of the ontology.

RESULTS AND DISCUSSION

Scope: The modelling of the academic programmes regulations ontology started with the definition of the

Table 1: Competency questions

No	Competency question
1	What courses are done in the different levels of a programme?
2	Which courses are Mandatory or elective at the different levels of a given programme?
3	What are the pre-requisites of a given course unit?
4	Which course syllabus have a specified objective?
5	Which programmes are available through the different forms of delivery?
6	Which programmes were reviewed within a given timeframe?

scope. Generally, the ontology is expected to provide a semantic layer to support enquiries and enforcement of academic regulations. The ontology is therefore expected to answer questions on details about academic programmes as well as support enforcement the regulations in systems used to manage programmes. For instance in course registration, the semantic layer can support checking if the candidate meets the registration requirements. The scope was defined using competency questions that the ontology should answer. The competency questions are outlined in Table 1.

Existing ontologies for reuse: Multiple ontologies have been developed to model academic programmes[9, 12, 17]. The Curriculum Course Syllabus Ontology (CCSO)[12] was found the most appropriate for modelling the targeted knowledge for this research. The ontology covers all nearly all aspects of academic programmes regulations with minor additions.

Ontology modelling: Modelling the ontology adopted the structure of the CSSO ontology[18]. The CSSO ontology has concepts and entities in for the academic domain and the programme regulations can be adequately defined using the structure. The development started with download of the current version of the ontology and removal of all individuals in the ontology as is recommended in the CSSO adoption guidelines. The key concepts identified for the academic programmes regulations ontologies were.

Academic programme: This is the main concept of modelling and the regulations are specified for the programme. Different types of programmes exists including doctoral, masters, bachelors, diplomas and certificates. Different regulations can be defined the apply to all programmes, those that apply to the different types and those that apply to the specific candidate programmes within these types.

Courses: This is the course units that are covered under each programme. There can be an overlap in courses that are prescribed for the different programmes. The combinations for the different programmes often differ and the weights that a course carries may vary from program to programme.

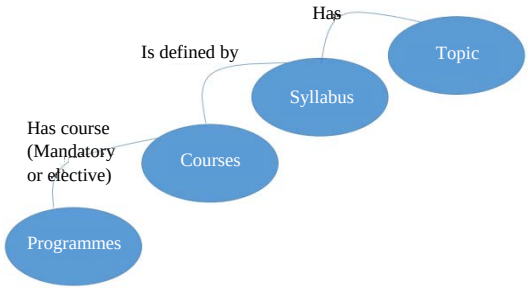

Fig. 1: Key concepts in the ontology

Course syllabus: This can be defined as the full set of topics that are covered within a course. The syllabus also spell out other rules that are applicable to the course.

Topic: This is a subject/discourse of study and several topics are usually combined to create a course syllabus. The relationships between these key concepts is outlined in Fig. 1.

The CSSO ontology provided most of the required classes, object properties and data properties for the regulations ontology. The data property included in together with its inverse includes course were used to associate a course to an academic programme. Modelling of the mandatory and elective courses was done by creating two sub properties of the object property; includes mandatory course and includes elective course with their respective inverse properties; mandatory course in and elective course in. These two provide the possibility to associate a course as mandatory or elective depending on the programme regulations. The same course can have different inclusion in the programme; in one programme or same programme different specializations a course can be mandatory and in another the same course can be optional. The modelling in the CSSO of defining a course as mandatory, core or elective as part of the properties of a course does not meet the programme structuring of the case institution and hence the adjustment. Some class and object properties amendments are shown in Fig. 2.

Representation of the course objectives utilised the syllabus and topic classes. Associating the course and syllabus was done using the has syllabus and its inverse syllabus of of object properties. Association of Topic to syllabus was done using the covers topic object property. The has prerequisite object property was amended to have a transitive characteristic. This is because the ontology is expected to support in the identification of non-conformance and enforce compliance as necessary. For example, if course A3 has a prerequisite course A2 and course A2 has a prerequisite course A1; the ontology is expected to check anyone registering for course A3 if they have completed all immediate prerequisite courses

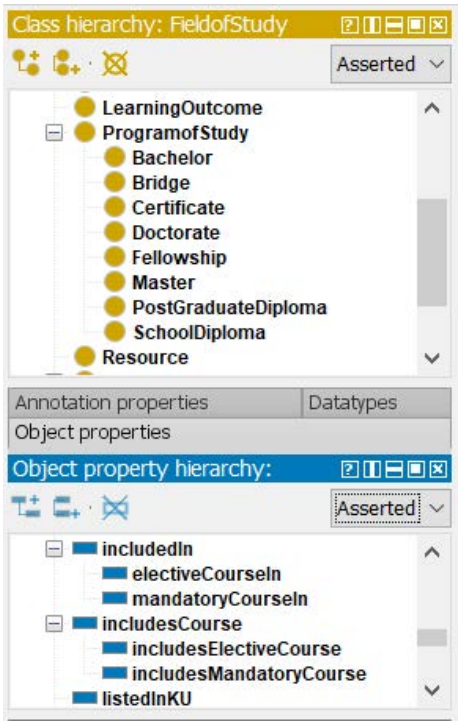

Fig. 2: Class and object properties amendments

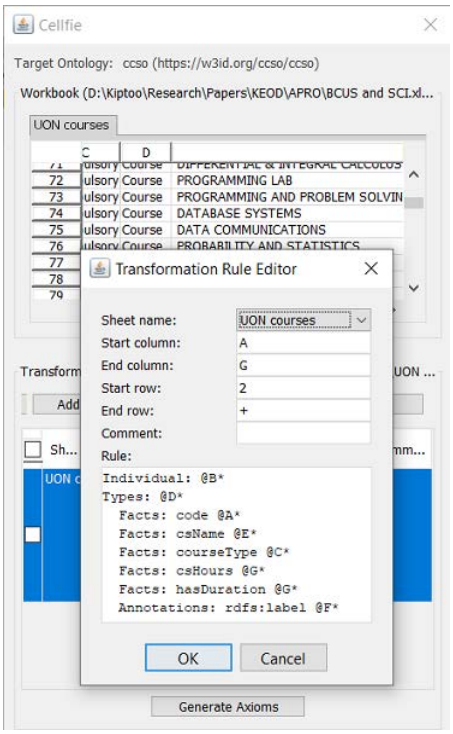

Fig. 3: Courses axioms import from Microsoft Excel

and also the prerequisites of those other courses. Making this feature transitive will support this check thereby making the ontology serve the purpose it is intended for. A few data properties were added, so as to support the objectives of the ontology. CS Hours was added and is used to represent the number of hours for the course. This is required for purposes of enforcing attendance to course events by the student since the regulations provide for minimum attendance requirements. status data property was added for the representation of the status of a programme or a course and can have active, closed, inactive or upcoming values. The date sub properties start date and end date were used to model the programme dates. A new property, revision date was introduced under the date data property to model programme revision knowledge of the ontology which is useful in enforcing revision cycles regulations.

The individuals of the different entities in the case institution regulations were captured. The process of capturing was done using the Protégé inbuilt tool for importing OWL axioms from Microsoft Excel workbook and manual capturing of axioms that did not already exist in structured format. The programmes, courses, organizational unit and teaching method were migrated from excel while the other regulations content was captured manually. The migration of courses from excel is shown in Fig. 3. Other content such as employees were not relevant to the regulations domain and were left out for the time being.

After setting up all the structural enhancements and migration of what could be migrated, additional assertions were represented using available interfaces in Protégé.

Evaluation: The evaluation of the ontology was done by checking if the ontology could answer the competency questions. This was done using the DL query in protégé. The DL queries used to check the ability of the ontology in answering the competency are outlined below:

Question 1: What courses are done in a given level of a programme?

DL query: Course and included in value P15_2020 and CS Level value “1”.

Question 2: Which courses are mandatory or elective at a given level of a given programme?

DL query: Course and mandatory Course in value P15_2020 and CS Level value “1”

Question 3: What are the pre-requisites of a given course unit?

DL query: Course and prerequisite of value CSC442_2020.

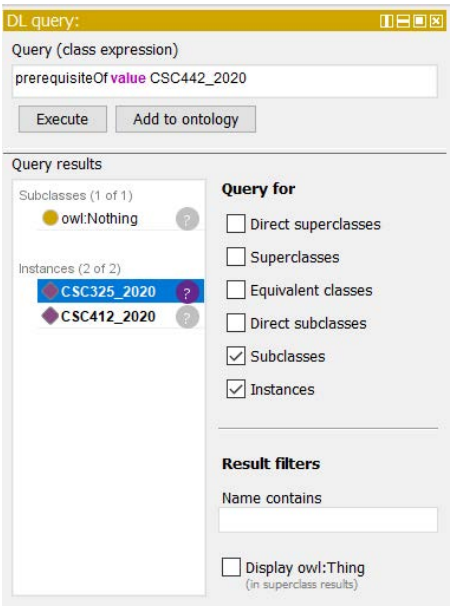

Fig. 4: Course prerequisites DL query

Question 4: Which course syllabus have a specified objective?

DL query: Syllabus and aims to LO value CS/SE/Programming.

Question 5: Which programmes are available through the different forms of delivery?

DL query: Program of study and has mode of study value work study.

The output from the DL queries output confirmed that the ontology provides correct answers to all the competency questions. In some areas, the ontology gave better results than the current RDBMS system. The main strength of the ontology over the database system is the ability to check for course pre-requisites exhaustively. The RDBMS system checks on immediate prerequisites but not the prerequisites of those prerequisites. The ontology supports a transitive check which is a major strength that the ontology will introduce into the system. In Fig. 4, a screen shot of the DL query output for Question 3 which was aimed at checking the course prerequisites.

The query results give two prerequisites for the course yet only one is asserted. Making the has prerequisite feature transitive made this important requirement of the ontology possible.

CONCLUSION

In this study, an ontology of regulations for academic programmes is presented. The creation of the ontology was motivated by the need to provide ontological support for the enforcement of the regulations. Ontological modelling relied on the CSSO ontology which models common concepts for the academic domain. A few modifications/enhancements were made on the CSSO ontology structure so as to fully support the objectives of the regulations enforcement.

Evaluation of the ontology gave correct results and therefore is promising in providing the much needed automated support for programmes regulations enforcement. The contribution of this work is the structure for representing academic programmes regulations knowledge and the ontology of the case institution's regulations which adopt the structure.

RECOMMENDATION

Future work will explore the integration of the ontology to the current RDBMS systems so that the ontology can provide the automated knowledge support for better enforcement of the regulations.

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