Authoring Tools for KOC – Concepts and Pedagogical Use

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ABSTRACT
One of the main problems of teachers aiming to teach the construction techniques used in to build a building is the lack of practical examples to show to their students. In order to be useful, these examples must come from real projects or even better the teachers may take their students to constructions sites, but this latter option is not always available and may be dangerous. To deal with this problem, Los Andes University has committed the construction of a knowledge repository containing information gathered from real projects and semantically described, in order to provide easy access to its content and in the language of people of construction. This project is called KOC, standing for Knowledge Objects of Construction, which uses an ontology to describe semantically the data contained in the repository. Being the pedagogical objective of the project, it is important to provide the teachers with additional tools to generate new knowledge objects, based on existing knowledge objects in the repository. This paper presents three composition tools for KOC: a complex objects composer issued from structured searches, a constructive processes composer and a case study composer, all of them aiming the improvement of learning quality in the technical area of building construction at the architecture and engineering schools. The paper also shows some examples of knowledge objects and how KOC is been used in the courses of the Architecture Department of Los Andes University.
1. Introduction

Undergraduate teaching in Architecture has been usually based on two types of courses: those with a theoretical nature, comparable to traditional university lecturing, and those emphasizing practice, known as project studios, in which the student acquires the skills of an Architect through the development of architectural design activities. This notion of architectural education, that has led to a situation in which professional practice is simulated in the classroom [1], without much questioning about the values and techniques of the discipline, was the main concern for a curriculum reform of the architecture program at Los Andes University (Bogotá-Colombia) in 1996. The main objective of this process, counting more than 12 years of work already, is to understand Architecture as a high-complex discipline, having a group of values and techniques clearly defined, and to develop pedagogical approaches to teach them in the academic field.

This complexity of construction courses in Architecture implies a great challenge to educators and researchers. Following the observations made by a group of professors in the University of Los Andes, while developing the Architecture syllabus [2], some situations ratifying this affirmation has been identified. Inherent restrictions to the constructive activity prevents the existence of hands-on courses, in which the students visit the construction sites in real time; for instance, the physical difficulty to access the site, security and risks of the visit, the difficulty to match the academic and the construction project calendars, among others.

As an alternative, some few teachers capture multimedia material by themselves (pictures, videos, interviews, etc.) or recover auditing material to give their lectures. Usually this data gathering process is informal, undocumented and arbitrary. Some disadvantages of this practice include the inexistence of quality criteria for the gathered material, that its use is bound to the own interpretation of the teacher; that students and other teachers can barely access it, leading to a limited and restricted circulation, and they can even disappear at any time. In other words this material is highly volatile, rarely updated or maintained, usually dispersed among several machines and finally there is a lack of a unified vocabulary to describe it. In conclusion, it is currently difficult to teach and it is necessary to simulate the best practices and methodologies in the construction projects.

For construction companies, the same problems arise. When new employees have to be trained or they want to make general sessions to update and training, they deal with: the lack of a corporative memory, because there no exists a systematic learning of errors committed in previous projects; there no exists collected quality material showing the best practices and company methodologies that can possibly diminish the learning curve of new employees; finally there no exists tools to facilitate this training.
The KOC project (Knowledge Objects of Construction) [3] faces this problem by means of five main axes. The first one structures the different concepts for building construction in Architecture and their relationships in an ontology, called ArCo (Architectural Concepts) [4]. The second one defines a formal process to gather quality data throughout the whole construction process of real projects. The third one allows the annotation of these collected data using the ArCo ontology and to store them into a knowledge repository. The fourth one provides a highly semantic searching and querying of content in the repository. Finally, the fifth axe, and main subject of this paper, it provides several authoring tools to generate complex knowledge objects, based on existing “simple” knowledge objects in the repository. The result is a repository of high quality architectural knowledge objects, clearly described, and re-usable. In addition, it provides mechanisms to high level queries, responding to architects (professional, teachers and students) requirements.

Concerning the fifth part of KOC, three prototypes has been designed and implemented. The objective of these developed authoring tools is to facilitate the work of experts in the domain of construction in Architecture, allowing them to construct, from existing objects of knowledge, new objects of knowledge, with greater conceptual level, and reenter them to the KOC repository. The first tool, the ArCo-based complex objects composer, allows the authors to relate existing knowledge objects by querying KOC for existing objects based on their annotations. The result is another knowledge object grouping the examples found in the repository; these examples aim to respond specific questions of construction in Architecture. The second tool, the constructive processes composer, facilitates the input and annotation of multiple activities showing the construction of a given architectural element, simultaneously; the process is also annotated using ArCo and becomes a new knowledge object. Finally, the case study composer helps the teachers to define and structure their own case studies, using the data and knowledge objects in KOC; it provides also some collaborative edition by several authors. Having these case studies in KOC, they can be used and updated easily for other teachers.

Unlike there exist other systems defining ontologies for the construction process in architecture [5] or defining taxonomies based on standards [6,7], KOC takes a pedagogical and learning oriented approach. When compared to other ontology based authoring tools ([8] and [9]), KOC, by narrowing the domain to technical area takes profit of its semantic in a more effective way, avoiding at the same time some possible over-simplification due to attempts to represent generic domains.

This paper is structured as follows: first it presents the main concepts of KOC and ArCo. The second part presents a brief description of the three composer, and their use in current courses at Architecture Department of Los Andes University. Finally, current state of KOC, some obtained results and some outcomes are presented.
2. Global vision of KOC

KOC is not the first intent to represent and publish architectural data. Another architectural knowledge base system is MACE [10], which connects various repositories of architectural knowledge and use metadata. These repositories provide services to search and browse architectural contents by conceptual connection, geography, language, among other.

Contrary to KOC, the data they have are full finished projects, they are not interested in the construction process and the main pedagogical objective lies more in the architectural design rather than in the spaces, systems and elements that compose the project. Some other architectural knowledge repositories are DYNAMO [11], UNESCO World Heritage List of Sites [12], Archiplanet [13] and MOOD [14].

This section presents the context in which the development of authoring tools takes place. This context is provided by ArCo, the ontology allowing the description of data, KOC, the knowledge objects repository, and how they are used to annotate the data and later to improve the knowledge generation by means of authoring tools.

2.1. ArCo: the ontology

ArCo (Architectural Concepts) is an ontology that structures a knowledge base in the technical area of the Architecture.

ArCo aims to respond several questions about the technical area of building construction.

- What can be constructed? It makes reference to the construction objects constituting the kernel of the ontology, represented by architectonic elements and spaces. Every construction object in ArCo represents an idealized instance to which real objects are related.

![Figure 1. Main scheme of ArCo.](image-url)
• Why or What For these objects are constructed? It makes reference to the intended functionalities and performance of these construction objects, in three fundamental categories: habitability, watertightness and stability.

• Where and When these objects are constructed? It makes reference to a Work Breakdown Structure (WBS) [15], which classifies the elements in systems, subsystems and elements and also defines the chronological order of activities leading to their construction.

• How these objects are constructed? It explains the choosing of materials, techniques and equipment to construct the element correctly.

Figure 1 presents a diagram of these concepts within the ontology and their relationships. A more detailed definition can be found in [3].

While structurally complete, ArCo cannot be considered complete, because it does not contain (yet) every element or space or equipment or material in the world of construction. It has been designed to grow continuously with the addition of new concepts every time it is needed. KOC implements a “concept request” strategy: When an annotator cannot complete an annotation because ArCo does not know a given concept, the annotator issues a concept request for this concept to ArCo administrator; the administrator study the request and gives solution to it, by eventually creating the new concept in ArCo.

At present time, the number of concepts held by the structure of ArCo has increased. Concerning construction objects, 325 architectural elements and 18 types of spaces have been included. There are now six main categories for the functionality of construction objects with about 125 specific functionalities and performance degrees. The Work Breakdown Structure (WBS) has grown to contain 27 subsystems and 105 types of elements within its 4 main systems. 18 construction materials have been recognized in four material families, which are commercially available in 58 presentation modes. 15 construction techniques in six categories have also been included in the system, as well as 57 construction tools and equipment in three categories.

2.2. KOC: The knowledge objects of construction repository

KOC is a knowledge repository of objects “talking about” the technical area of construction in Architecture. The main functionalities provided by KOC include the access of data and collaborative edition to students, professors and professional architects in general. KOC has four fundamental parts: The implementation of ArCo, the process for data gathering, specified in [16], the input and annotation of these data using ArCo and high level semantic querying to the repository. Each part is of vital importance and their simultaneous operation supports the utility of the system.

Being KOC a Web application, it allows remote access to the repository from any device having Internet connection and a browser; it implements
also some control mechanisms to deal with the system security and data integrity. Figure 2 shows a screen of the KOC Web interface.

The KOC strategy consists of incrementally adding knowledge as shown in Figure 3. The first step is the raw data represented by a file and its metadata (dates, project, the architect, type of media, author and location, among others); the second step annotates the data in terms of ArCo, turning it to a simple knowledge object. Once two or more of these simple knowledge objects are related and tied by means of an authoring tool, they conform a complex knowledge object. Finally, as a future work of the project, these knowledge objects may be enriched with learning and pedagogical metadata, allowing the definition and management of learning objects, making possible then to follow the learning process of students.
2.3. Knowledge objects and annotations

Knowledge objects are high level entities extending the gathered raw data with additional information and annotations, which could be considered as added knowledge. This knowledge includes the kind of data it is (a picture, for example), the associated building lifecycle (design or construction, for example), the granularity of knowledge that is being used to describe the object (subsystem or activity level, for example), a global qualification indicating whether the object represents a good practice or a bad practice and finally the annotations.

The annotations make explicit the relations among the concepts defined in ArCo and the collected data coming from real projects. The annotations are the bridge joining the ideal instances defined in ArCo and real examples of construction stored in KOC. Besides these references, annotations can contain additional information enriching the knowledge object.

A formal definition of Knowledge Objects, in BNF format, is:

\[
<KO> ::= <Simple KO> | <Complex KO> \\
<Simple KO> ::= <Data><Annotation>^* \\
<Complex KO> ::= <Annotation><KO>^* \\
<Data> ::= <Raw data><Metadata> \\
<Annotation> ::= <WBS annotation> | <Material Annotation> | <Functionality Annotation> | <Equipment Annotation> | <Space Annotation> \\
<Raw Data> ::= Image | Video | Interview | Document | Chart | Plan | ... \\
<Metadata> ::= Author | File format | Date | Project | Architect | Location | ...
\]

Figure 4 shows an example of a simple knowledge object referring to a metallic truss construction element (Cerchas metálicas in Spanish). Annotations concerning WBS, functionalities and material are shown below the picture.

Figure 5 shows a complex knowledge object representing the whole construction process of a scale model. The information on each stage can be expanded, until simple knowledge objects, as shown above.

2.4. Current repository content

Three major construction projects, built in the university campus (Figures 6 and 7) in the last three years, have been the main source of information for data gathering. The Mario Laserna building, reaching 44000 square meters of construction, serves the university’s general library and the Engineering School with its significant laboratories; the ‘W’ building, with a more traditional architectural brief, contains classrooms and offices; and the Sports center, built in a steep terrain, implied several structural and
technical challenges. Following the previously defined monitoring protocol for constructive processes, a work team produced multimedia documents capturing different aspects of the construction processes of the three buildings. Given the variety of architectural problems and solutions, this
base of information covers a relatively wide range of concepts and learning objects of building construction and the technical fields of Architecture.

Considering the content generation, there is a great data volume coming from several construction projects in the University, which populates KOC incrementally. Current metrics show a total of 827 data, 7100 annotations and 5 projects.
3. Composition and authoring tools

The initial version of KOC contemplated only the annotation and input of knowledge objects of construction in an atomic way: Each knowledge object was completely independent and it was not related to any other. An evident KOC evolution is to define and manage relationships among these “simple” knowledge object, in order to conform knowledge objects of greater conceptual level and finally store them into the knowledge repository.

Depending on the desired relationships, the generation of these new complex knowledge objects could be a difficult and expensive task for knowledge generators. In order to facilitate this process, it is desirable the construction of authoring tools, allowing the creation and incorporation of high level content to KOC repository in a clear and simple way. These tools improve the authors’ expressiveness, when supported by ArCo.

This document presents three authoring tools aiming to facilitate the work of content generators in KOC, improving then the quality of education in Architecture schools: a complex objects composer, a constructive processes composer and a case studies composer.

3.1. ArCo’s based complex objects composer

The complex objects composer is an ArCo-based authoring tool, allowing the creation of new knowledge objects, using already existent knowledge objects in KOC. The knowledge generator issues a query to KOC using the concepts in ArCo, as for example “Give me the knowledge objects showing good practice techniques to build a structural column”; the composer takes the results of this query (the data and their annotations) and generates a new PowerPoint document with them, and also an initial annotation for the new knowledge object; the author may edit this document to fulfill his purpose and may edit also the annotation to reflect the changes; finally the author may include the new knowledge object into KOC repository. An immediate consequence of using this tool is the reusability of existing objects in the repository, generating networks of semantic links among them. Figure 8 shows the process followed by this tool.

The main purpose of this tool is the systematic grouping of objects of simple knowledge sharing similar characteristics (by querying their annotations) in order to conform a high level object with some pedagogical

![Figure 8. Process of complex objects composer.](image-url)
This new object can be presented in the classroom or viewed with a WEB browser, according to the teacher’s indications. Another use of this tool could be to gather answers to common time consuming questions that professionals have: They will not have to browse the whole repository searching for the desired information. The main users of this tool are the teachers: They query KOC according to the concepts in ArCo in order to introduce a given subject for their lectures and to show real world examples following ontological concepts. The other users will be able to view the complex objects generated and use the KOC mechanisms to suggest the addition of new complex objects. Figure 9 shows an example of a knowledge object built from four other knowledge objects.

3.2. Workspaces and constructive processes composer

This section explains two of the basic authoring tools, the workspaces and the Constructive Processes Composer, and how they were successfully used in one of technical area courses of Architecture Department.

A workspace is a conceptual buffer in the repository created by a professor for his students to upload data. From the beginning of the project it was sought that the students were able to use it, but it came up the problem that some data and knowledge objects that they uploaded to the repository may not have the required quality. So, the workspaces were created to keep the data from the students separated from the rest. Once the students upload their data and annotate them, the professor makes a revision and depending on their quality they can be approved, disapproved or let pending (meaning that the student must do some minor changes to get it finally approved).
On the other hand, a constructive process is a sequence of chronological activities, whose final result is a finished construction object. The constructive processes composer is a tool to generate complex objects grouping all these activities as a whole: it supports the annotators in the input of multiple simple objects, at least one for each activity, simplifying the annotation process, because common descriptions are issued only once. The individual information associated to a given data includes its order in the sequence, its duration, the involved personnel and the qualitative grading of the activity. The composer also generates a PowerPoint presentation with pedagogical purposes, showing slide by slide each activity carried out during the construction process. The current implementation supports constructive processes for architectural elements like columns or beams, but also constructive processes of spaces like offices, auditoriums, etc. Figure 10 shows the process followed by this tool.

The purpose of this tool is to accelerate the process of annotating constructive processes by reusing the common annotations to each activity: all of them concern a given element (a column, for instance) and it is not worth to give this information for each data. Contrary to the Complex Objects Composer, this tool does not require that all objects exists in KOC: Given n raw data representing a construction process, the composer generates \((n + 1)\) knowledge objects, \(n\) for the individual activities and one for the construction process itself. The main users of this tool are the annotators, because they are in charge of the data entry to the system.

These tools have been used for a practical exercise in the Technical Workshop 1 course at the Architecture Department of the university. Second-year students are asked to build a 1:50 scale architectural model, consisting of a hybrid structure of concrete and wood along with its foundations on a modeled terrain. The pedagogical objective of this course emphasizes on the work with real materials, in such a way that the construction techniques used are not far from the real ones employed in construction projects. The pedagogical support of KOC started with an invitation for the students to browse knowledge objects coming from real life projects, showing and explaining the construction objects and processes, totally comparable to those they are to build in their model. Also, they were asked to check the conceptual structure proposed by ArCo, with the
purpose of identifying the contents of the course as part of a greater body of knowledge. Then, the system was used to monitor the process of the model for each group of students: for a six weeks period, while the construction of the model took place, the students were required to take and upload photographs and make the corresponding annotations in KOC. Only the second part of the exercise, the one involving monitoring and annotating, was checked and graded by the teachers.

In the first semester of 2010, 80 students, in 20 groups, generated a total of 447 simple knowledge objects and 39 complex knowledge objects corresponding to different constructive processes.

This experience left a number of learned lessons for the KOC project. The fact of having a considerable group of students working simultaneously and generating content was a test that the application passed satisfactorily. Some usability problems were reported by the students and some were solved immediately and others are in implementation process. In some cases, the annotations quality was rather low, showing that some of the students were not aware of the expressive power provided by ArCo. This is a very important lesson for a future uses of KOC in other courses and exercises: the first contact that a user should have with the system is a careful recognition of ArCo. Then, navigation through the KOC repository should give the user the acknowledgement of a high quality annotation. After this, the user could be able of making good quality annotations.

3.3. Case study composer

A case study is “a description of a situation from the perspective of the protagonist” [17], serving as a metaphor to teach the student to solve generic problems with the same kernel [18]. The case study composer allows the teachers to define and structure their own case studies by constructing a decisional graph of situations (nodes) and transitions (arcs), leading to situations that result from the choice of one of the alternatives. In order to understand the making decision process, the situations are

![Figure 11. Process for the case study composer.](image)
composed by the problems, goals, advantages, disadvantages and the information to make the decision, usually represented by knowledge objects. The result is a directed finite deterministic and noncyclical graph. Figure 11 shows the process followed by this tool.

The main purpose of the tool is to help the teachers to systematically structure their knowledge as case studies, taking advantage of existing contents in KOC repository to illustrate the desired situations: The author may use the query facilities provided by KOC in his search of situations for his case study. The case studies issued by the composer can be extended, complemented or tied to other case studies from other authors, leading to a collaborative environment. By using this composer and the vocabulary proposed by ArCo, it is possible to capture and make persistent the teachers’ knowledge in a reusable pedagogical format. The case study methodology – and this composer in consequence - promotes the Socratic pedagogy: learning by doing. The composer also looks for the reuse of the knowledge produced in real construction scenes in the classroom, allowing the creation of networks of relationships among pedagogical materials and practical knowledge.

A case study for the Telefónica offices in Bogotá was generated and part of the decision network is shown in the Figure 12.

The Colombian government sold Telecom S.A. to Telefónica and a group of architects were given the task to design and build the offices of Telefónica. In the figure, the pale pink nodes represent the decision path taking by the architects. This case study can be shown as a whole to the students, or browsed interactively, showing only a situation at a time and then ask the students what are the alternatives? What his solution would
be? Give the justification for your choice, and other questions. Finally the system shows what the architects really did, and students can compare their solution to the “real” one. In this way, it is expected that students develop a more rational decision making process.

4. Results, current state and future work

The current state of KOC project can be seen from different perspectives: the conceptual definition, the development of the software application and content generation. From the conceptual point of view, after several revisions and iterations in the design of ArCo and the underlying concepts, a maturity stage has been obtained, reflected by its expressiveness to describe construction objects and all their features. ArCo respond to basic necessities of annotators and its “concept request” system joined to some management facilities makes possible to extend it in a controlled way.

Regarding its development state, KOC has also several versions, issued mainly from users’ feedback, improving the usability and interaction schemes. In terms of infrastructure, KOC becomes every time more reliable and more scalable.

As a whole, KOC has a good acceptance in the academic environment; it has been presented in several national and international conferences and has been also awarded with international grants.

Nevertheless, KOC could be improved in several ways, including the addition of new functionalities, the integration with other systems, its use in other contexts and the internationalization of the repository, among others. Figure 13 shows the scheme of some possible future modules: the creation of new authoring tools, teaching and learning tools, mobile KOC, social KOC, and many more.

5. Conclusions

The KOC project has already shown great benefits by its application in academic contexts. Its contribution does not have to be limited by the
effort that represents for the authors the elaboration and querying of high level knowledge objects. The authoring tools try to deal with this problem by helping the authors to define and structure new complex objects with higher semantic level, ready to be used by students but also for software agents in the Semantic Web.

Regarding the experience of KOC and specifically the use of ArCo, it has been demonstrated the effectiveness of the use of ontologies for knowledge formalization and management, to ensure communications among teachers and students, and to make explicit the semantics of the technical area in Architecture. Nevertheless the potential use of ontologies can be also profited by using them as a technology for data integration, possibly among several instances of KOC or with other systems.

References
