Enhancing Learning Objects for Digital Education

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***Abstract*—This research presents a method to describe Learning Objects as Semantic Web compatible Ontologies. The proposed method divides the Ontologies among three layers. The first is composed of the knowledge domain, the second by the Learning Objects (LOs) and their relations, and the third is responsible for knowledge inference and reasoning. As study case, we present the Ontologies of Learning Object Metadata (LOM) and Brazilian Metadata for Learning Objects (OBAA) metadata standards as part of the Layer One. The Layer Two composed by the description of sample Learning Objects based on the properties and restrictions defined by the Layer One ontologies. Layer Three describes the knowledge inference axioms, which we defined as Application Profiles. Our current results can summarize a contribution to Ontology Engineering for Semantic Web applied to Digital Education.**

***Keywords*–Digital Education; Adaptive Learning; Computational Intelligence; Mobile Computing; Smart Environments.**

I. INTRODUCTION

Technology Enhanced Learning has the purpose of easing the knowledge retention and improve the learning performance in formal, non-formal or informal environments. Researchers and companies are always exploring new educational methodologies and artificial intelligence algorithms seeking to find the “secret recipe” to help teachers increase the educational performance of their students.

Despite current achievements, [1], [2], [3], are skeptic regarding formal learning in classrooms. According to these authors, there is no clear evidence that the usage of technology in classroom environments can increase the learning retention. We believe that there are two main causes for that: (i)the lack of standardized technological artifacts (Learning Objects) for sharing of educational content between students and educators [4], [5], [6] and (ii) the focus on the role of technology as support to current pedagogical models, provide class statistical analysis[7], [8] and enhance ludic experiences. This research will focus on the item (i).

Nowadays, we have a plethora of alternatives to access information. Television, the Internet, and mobile devices are platforms that ease the access to several kinds of educational contents. Many of them are hard to reuse [9]. The challenge resides in designing Learning Objects that are standardized, easy to share and able to leave a trace of performance measures among its application in different educational domains.

To deal with such complex domain that involves variables such as usage context, academic profile, cognitive styles, among many others, we believe that the technologies of the Semantic Web [10] and the Knowledge Representation and Reasoning [11] seem to be promising.

The contributions for educational systems can be classified in three areas [12]: (1) Information Storage and Retrieval; (2) Autonomous Agents and Artificial Intelligence Inference and (3) Communication and Information Persistence over time. In this research, we are focusing on Information Storage and Retrieval.

Considering this, we must comply with variables that are related to the learning progress of a student. It is perceived from many perspectives (e.g., Pedagogy, Philosophy, Psychology, Human Computer Interaction) [13]. It became necessary to design a flexible and interoperable approach to model the Learning Object and those variables inside educational environments [14], [15], [16]. We believe that this is the first step to achieving large-scale personalization [17], [18] in educational systems.

Therefore, we propose a method to use the standards and technologies of Semantic Web associated with ontological representations to describe Learning Objects. Also, we present our findings and experiences developing and deploying Semantic Web Learning Objects.

The rest of the paper is structured as follows. Section II presents detailed information regarding the built Knowledge Representation; Section III discusses the challenges and opportunities to explore this work further and, in Section IV, we provide our concluding remarks and future work.

II. BUILDING THE KNOWLEDGE REPRESENTATION

The users in educational domains can be classified according to their roles. They can be teachers, students, tutors, administrators, between several other classifications; Learning Objects are digital or non-digital; and the relationships between the user(s) × Learning Object and user × user, have several associated properties. For example, Learning Objects can be associated with content relation; users can be related to authorship or activity like assessment, sharing or reading.

There are alternatives in the Knowledge representation and reasoning area to represent this kind of domain. We choose to use Ontologies due to their popularity and availability of design tools for Semantic Web. Web Ontology Language (OWL) ontologies were the most nature choice since it is based on description logics. This representation allows to cope with incomplete information and also to manage consistency check of the students profile during information updates.

The proposed ontologies are divided into three layers. The Layer One is composed of ontologies that describe metadata schemas, for instance, the Learning Object Metadata (LOM) Ontology; Layer Two ontologies describes a User Profile, Learning Objects or their relationships with properties from a Layer One Ontology; and Layer Three Ontologies comprehend the description of Applications Profiles that will provide reasoning over the Layer One and Layer Two.

ISBN: 978-1-61208-531-9

To describe the method we use several key terms of OWL ontologies: **Class:** describe concepts of a domain, a structure that can encompass a set of Data Properties or Object Properties and individuals; **Properties:** is a binary relation on individuals; **Object Properties:** relations between individuals; **Data Properties:** relationships among individuals and an eXtensible Markup Language (XML) Schema Datatype value or a literal; **Axiom:** a premise or a point to begin the reasoning process; **Range:** links a property to either a class description or a data range; **Domain:** it is used to link a property to a class description; **Cardinality:** it is a restriction, defines the maximum or minimum number of individuals to link with a property; **Individuals:** represent the objects in the domain that we are interested in.

A. *Describing Layer One Ontologies*

The first thing to consider is the application domain: A Standard for User Profile representation; an educational metadata standard; a relationship standard; among other possible top layer descriptions.

The Layer One ontologies are used to describe classes and properties that are used to represent individuals in the Layer Two ontologies. This layer stores ontology with the semantics of a metadata schema, considering: cardinality; data ranges; association properties; and the necessary axioms to describe the application domain.

For example, Layer One ontologies can comprehend LOM Metadata Standard [19]; Brazilian Metadata for Learning Objects (OBAA) metadata standard [20] or Friend of a Friend (FOAF) metadata standard. The nature of those ontologies regards properties to describe a context, a domain or their members.

To design Layer One ontologies, we propose the following set of practices: Metadata classes became OWL Class and OWL Subclass; Metadata Properties became OWL Data Properties and OWL Object Properties according to their semantic; We describe the semantics of metadata as restriction axioms.

Building Layer One Ontologies regards the definition of the properties that are necessary to describe the Layer Two individuals and the Layer Three ontologies Application Profiles.

We define a few steps to follow to describe this kind of ontology:

- Study and understand the whole standard;
- define the set of Classes and Properties exactly like the standard incorporating their Ranges and Cardinalities;
- choose a Reasoner to test the ontology;
- provide a Universal Resource Identifier (URI) to publish the ontology.

To exemplify the design of Layer One Ontology, we will use as case study the LOM Metadata Standard for three reasons: LOM is considered an international standard to describe Learning Objects [21]; It is commonly used by researchers in educational technology, and, there is an opportunity to describe a standardized LOM OWL ontology.

LOM is a massive educational standard. We will define some classes and properties. The chosen LOM group (LifeCycle) is sophisticated enough (cardinality restrictions, domain, and range restriction) to demonstrate our method. The LOM ontology is available to reuse through the following URI [22].

We choose to present the study case using the LOM LifeCycle group because of its characteristics. It is relatively small but preserves the semantic complexity of the larger groups, such as General or Educational. Following we present the Classes and Properties described according to our ontology engineering approach. The LifeCycle group shows the LOM metadata Standard group 2.

a) Defining the Classes: Each metadata from LifeCycle group becomes a class and a subclass with cardinality restrictions according to the chosen standards. For instance, Contribute is a subclass of Life Cycle and has a cardinality *max* 30.

b) Defining the Properties: Properties can be classified as Data Properties or Object Properties. Data Properties are the data itself (e.g., *has_name* String "James"). Object Properties describe the relationships between classes and individuals (e.g. *has_classes*). Object Properties are also associated with the metadata cardinality (e.g., Max 10 *has_classes*)

The cardinality restrictions can be used with Object Properties. They can be used to group individuals with specific characteristics. As an illustrative example of those relationships, refer to Figure 1.

In Figure 1, at its center, it is illustrated a sample **Learning Objects Individual** that is divided into two parts. The number one (1), shows a generic Learning Objects representation model; The number two (2) illustrates the usage of the Object Properties Contribute, in this case, named LOM:hasContribute. As can it be seen, there are three individuals represented. The higher Layer **Learning Objects Individual** and two other ontological individuals linked by the Object Properties LOM:hasContribute and each one of them with specific Data Properties.

This kind of relationship allows, for instance, the reuse of the individuals **LO + LOM:hasContribute + ID1** and/or **LO + LOM:hasContribute + ID1** in different versions of Learning Objects.

This example was prepared to exemplify the description of Learning Objects with such ontology engineering method; the next section will present the characteristics of the Layer Two Ontologies.

B. *Describing Layer Two Ontologies*

The Layer Two ontologies have the role in describing User Profiles, Learning Objects and their relationships during their life-cycle in an application domain. These ontologies import the properties of the *n* Layer One ontologies allowing the standardized description of individuals.

These ontologies can be stored in some formal repository, e.g., a Triple-Store, or even just defining a URI for its access. This alternative gives flexibility to content designers that can only build and publish their contents on the Web.

As a plus, it is possible to apply reasoning algorithms to verify the consistency of an individual trough some Layer One ontology. For instance, if we describe a Learning Object as an ontological individual of the LOM Layer One ontology, we can verify if the cardinality, range, and value space were correctly used. Also, if some description is incorrect we can apply an *explanation* algorithm to understand what was described wrong.

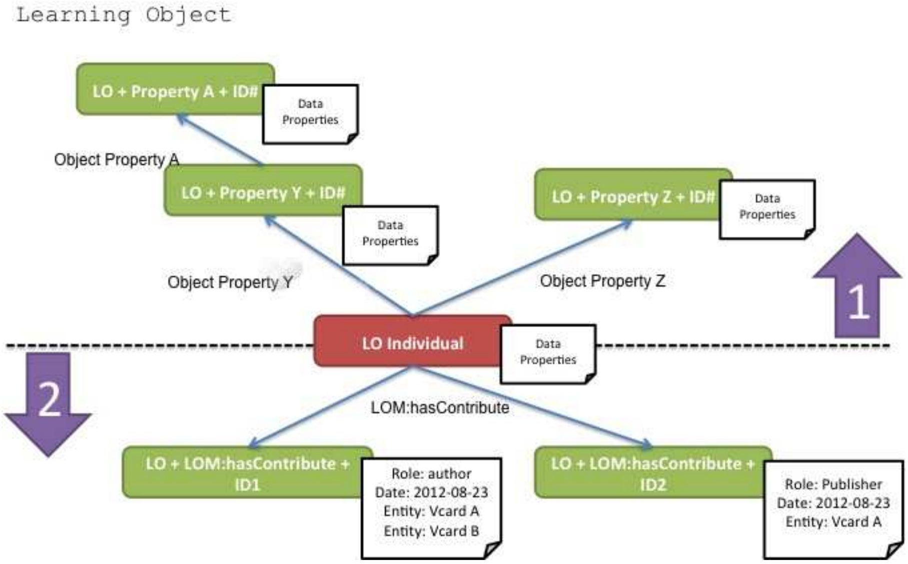


Figure 1. Sample Learning Objects with Life Cycle information

Layer Two ontologies are appropriate to describe: User Profiles; Learning Objects; application contexts; and relationships. Each one of them can be described in one or several ontologies. There is a hurdle to consider when dealing with granularity matters. Higher granularities allow by on side to delimit the processing unities and reduce computer processing, but, by the other hand, the human cost to break the information in several ontologies are elevated. We need to take this into consideration when describing an application domain with this method

For example, the description of a Learning Object as instance of the LOM ontology is performed within the following steps: convert or create a Learning Object; create an OWL file to represent the information of the Learning Objects; import the LOM OWL ontology; describe the individuals to represent information of the Learning Objects; create Object Properties and Data Properties relationships as necessary.

To illustrate this scenario, we present the *Ramis* Learning Object. *Ramis* uses two metadata standards, IEEE-LOM and OBAA. The underlying purpose for its creation was to simulate the description of an interoperable Learning Object compatible with three hardware platforms: Internet, Digital Television, and Mobile Devices. We started our conversion by analyzing that meta-information and illustrate its complexity with Figure 2.

Figure 2, has the indication **1** that emphasizes the higher layer individual; the indication **2** the Object Properties *hasRequirement*; the indication **3** the Object Properties *hasPlatformSpecificFeatures*; the indication **4** emphasizes the Object Properties hasSpecificRequirement; The indication **5** the Object Properties hasSpecificOrComposite and finally the indication **6** the Object Properties hasOrComposite. Each individual has its own set of Data Properties.

C. Describing Layer Three Ontologies

Layer Three ontologies are mainly developed to represent Application Profiles. [23] defines an Application Profile as compositions of metadata elements from one or more metadata schemas. They are used to describe an application domain.

This work adds to the application profiles computations means to reason knowledge and verify the consistency of Layer Two individuals. This process can be used to derive, for example, the users that have specific pedagogical characteristics, which Learning Objects can be used in a particular domain. Those inferences are made exploring the deduction rules of OWL ontologies.

An Application Profile ontology will be composed, at least, of a class with an axiom that will infer the individuals that match the axiom description. For example, we can create a class *UsersWithSpecialNeeds* with an axiom that describes that ontological individual with the property *hasVisual* is inferred as an instance of the class *UsersWithSpecialNeeds*. To create Layer Three ontologies we can use as many classes with domain axioms as necessary.

The Layer Three ontology is in charge of the reasoning over the Layer Two ontologies. To this proposal, we classify this type of ontology as Application Profile. Application Profile is an ontology composed of a class or a set of classes that describes specific domain knowledge and has at least one axiom for reasoning.

The reasoning is useful to verify if a Learning Object is adequately described according to some standard; to provide inferences according to specific domain characteristics; infer new relationships between Learning Objects; to support some analytical processes; among others.

To describe the Application Profile OWL ontology, we must consider: What is the knowledge to be derived from the Layer Two ontologies? Is it possible to retrieve by an SPARQL query? Reasoners are not extremely powerful; one axiom is enough? How many classes are necessary?

As an example, we shall describe an Application Profile that will infer Learning Objects, only if this Learning Object has a particular set of metadata. Considering this, we present the OBAA Lite Application Profile. This Application Profile was developed by [24]. The current research used OBAA and LOM standards to define the minimum set of metadata

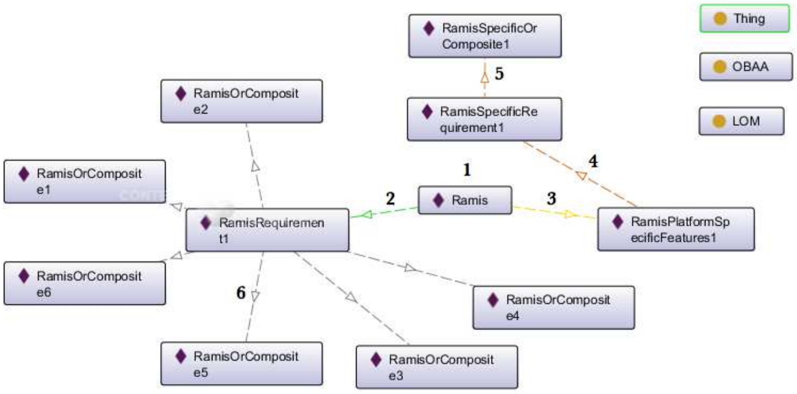
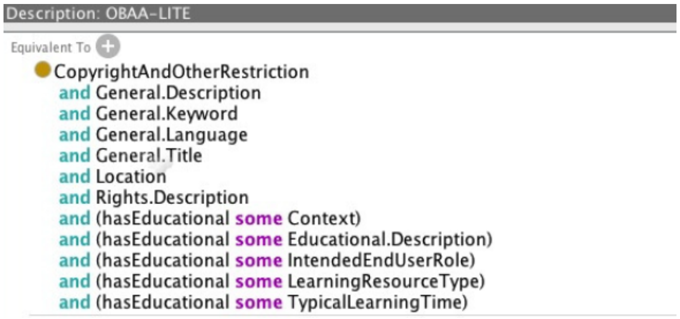


Figure 2. The representation of individuals for the *Ramis* OWL file



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and (hasEducational some LearningResourceType)
and (hasEducational some TypicalLearningTime)

Figure 3. OBAA Lite Ontology Axiom

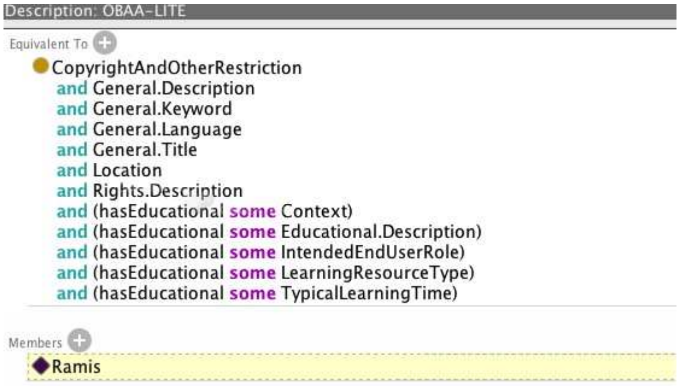
information that is necessary to describe domain specific Learning Objects. Figure 3 presents the class and the axiom built to infer which Learning Objects are compliant with the OBAA Lite Application Profile.

The current version of *Ramis* ontology does not get inferred by the OBAA Lite application profile because it does not comply with its axiom. To have it correctly inferred, we had to add the missing Data Properties and Object Properties to cope with the OBAA Lite Application Profile. The modification has resulted in the classification of *Ramis* as a member of the OBAA Lite Application Profile class, as can be seen in Figure 4.

III. DISCUSSION

There are several application development alternatives for the educational domain. We can explore the authorship of Learning Objects, development of Agents for Personalized student courses, the suggestion of educational materials among others. The present work had shown an alternative to represent User Profiles and Learning Objects by ontologies to allow a reasoning alternative for educational applications based on Semantic Web. We classify this research as part of a broader overview of an integrated ecosystem for digital education.

The use of computer technologies complements formal or informal education. Educational system designers must think about the teaching and learning process before building digital education platforms. The pedagogical plans, educational contents, assessment and learning feedback, should be integrated to allow the support of Artificial Intelligence (AI) algorithms, learning analytics or statistical measures.



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Ramis

Figure 4. The *Ramis* Higher Layer individual as member of the class OBAA Lite

Those algorithms were intended to analyze the students learning performance according to the teacher's pedagogical behavior, learning style and inference of students behavior to provide warnings and suggestions that can improve the learning performance and support the teacher educational activities. To accomplish this, we must think about an ecosystem for digital education.

Teaching with the support of educational technologies should improve traditional non-digital methods and support the three stages of learning (exposure, process, and feedback). Usually, a teacher of mathematics preparing a class about trigonometry, will search for concepts such as sine, cosine or tangent at a school library, ask for word-of-mouth suggestions, on-line websites, or even reuse previous classes materials. We classify this as the Step A: Content Gathering.

After the selection of educational contents, the teacher, based on experience gathered by years of student observation, will organize the materials considering the average educational performance of students. We classify this as the Step B: Class organization.

Once the teacher organized the class, it is time to provide the contents to the students and teach. We classify this as the Step C: Class execution. Finally, the teacher will go home, or to another class, the analysis of the success of the class will be measured by assessment feedback, emotional responses, or, in the next student's essay. We classify this as Step D: Signals Processing. Those steps, are the core scenarios of a class, before the Execution Phase.

The Execution Phase is the holy grail of teachers. It can use different kinds of educational contents, various personalization features, pedagogical practices and methods of evaluation. The essence remains the same. The role of educational technology regards the design and adaptation of Components to support each Phase of this process, allowing a Feedback and Personalization Phase to support the teacher activities.

Let us repeat the exercise of imagining the mathematics teacher preparing a trigonometry class from a different perspective, the AI of an Integrated Ecosystem for Digital Education. For that, we start backward, from the Step D: Signals Processing will be the beginning. At this point, we can analyze the student's interactions with the educational contents from the Step C. The time spent on each question, their number of tentatives for solving puzzles, comments, among an infinite set of signal capture possibilities. AI algorithms can cope with the Step B and use the Learning Objects from Step A, by processing and reasoning over the learning signals; identification of usage patterns; measuring the students learning performance; identifying competencies to be developed; measuring the engagement within a class and consequently suggesting content compositions based on a measurable class learning profile.

The challenges to accomplish such ecosystem reside in open architectures, metadata standards, communication protocols and policies regarding data privacy and security of students and teachers. Also, we need to consider a standard knowledge representation alternative to cope with information interoperability.

The benefits are far from being explored. For example, the detailed usage logs for in-classroom data collection and analysis can be used to analyze and infer pedagogically relevant data streams. Those data streams can be used to measure the student engagement in Real-time or After-class.

The real-time analysis supports the teachers during their classes. Those real-time analyses are challenging since they have to establish a time-frame of signal analysis, e.g., last 30 seconds of data, which variables to choose such as students eye tracking, page navigation, open content, the type of material, students emotional inferences, among others. Mainly, the research focus resides in the analysis of context similarities between what is being thought and what are the reactions of the students to it.

After-class measures support the teacher after and before the class. They compute the percentage of students that were engaged at each time-stamp, supports the teacher by presenting a timeline of the course. The research at this stage can be extended by deep-learning algorithms to infer the model of learning from students or groups, recommender algorithms, understand the behavior of students based on past actions, and other big data statistics to support class preparation.

When dealing with this kind of data, it is an open ground for research to identify what type of students and teachers events may be necessary to build richer models of student learning.

One of the challenges resides in assessing how well a student learns the subject matter, without explicitly testing for that in an exam. Thus, it is necessary to incorporate the metrics into a greater model of student learning.

For instance a knowledge map, based upon which new content could be suggested following what the student already knows, how engaged he or she is, the learning style, and other extracted metrics to personalize each students learning experience. Alternatively, the parameters may be used to design targeted interventions in the teachers activities, for instance, alerting him/her that the class engagement level is dropping. Nevertheless, such interventions must be designed together with educators to augment the teachers experience, and not disrupt his/her day-to-day work.

The work of [25] divides the Semantic Web educational applications into three columns. This article was able to contribute with the two first columns. To cope with the first column, an alternative to reduce computational costs related to exploring SPARQL queries for simple application profiles. e.g., search Learning Objects with a particular property value. Our primary challenge will be to reuse the educational ontologies that are already available and are not compliant with Semantic Web. Also, privacy is a delicate matter, especially in this case when dealing with private and personal information.

The proposed method was built to consider a three layer proposal for ontology engineering. It is important to mention that the LOM ontology is considered complex due to its specifications and restrictions. This fact, in some cases, caused the reasoner to be overwhelmed with ontologies of the Layer Two that were composed of many individuals. An alternative could be to separate each group of the LOM metadata in a single ontology. In the best case scenario, the reasoner would only have to cope with a limited set of properties.

IV. CONCLUSION AND FUTURE WORK

There can be several application development alternatives for the educational domain. We can explore the authorship of Learning Objects, development of Agents for Personalized student courses, the suggestion of teaching materials among others. The present work had shown an alternative to represent User Profiles and Learning Objects by ontologies to allow a reasoning alternative for educational applications.

The given ontologies made use of the three layer proposal to describe the knowledge domain. In each one, we described and presented an example of them. The LOM ontology is considered complex due to its specifications and characteristics. This fact, in some cases, caused the reasoner to be overwhelmed with ontologies of the Layer Two that were composed of many individuals. An alternative could be to separate each group of the LOM metadata in a single ontology. In the best case scenario, the reasoner would only have to cope with a limited set of properties.

Layer Two ontologies deal with a complex set of Data Properties and Object Properties. Although it can be considered a complex ontology, in an automatic process we could obtain several exciting benefits such as Easy update, for instance, an individual that is updated can be linked through an Object Properties.

The reuse of some ontological individuals by other Learning Objects, for example, a technical individual that is common to several other Learning Objects.

The described individuals can be validated according to a Layer One ontology making it possible to build relationships between Learning Objects ontologies by properties and compatible with the current Semantic Web stack.

The method to build a Layer Two ontology can be used to describe the user profile ontologies, educational domain ontologies, relationship ontologies, or any other that might describe an educational activity. Such amount of relationships can lead to performance issues, in particular by the reasoner.

There is a lot of work that still needs to be done, especially when considering students privacy matters, content usage rights, security policies over such information and, not most important, public policies that stimulate and popularize the principals of open knowledge leading to a large-scale evaluation that can measure the effectiveness of this approach for the current learning system.

As future work, we will explore a Triple-Store alternative to index and store Layer Two Ontologies such as Learning Objects (LOs), User Profiles and Relationships between them.

A Service Oriented alternative to integrating this proposal with some current educational application and describe new application profiles, to evaluate if the use of OWL-DL is the adequate solution to represent such kind of knowledge and explore the automatic conversion of Legacy Learning Objects Repositories according to this proposal.

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