A diagrammatic language to build and share STEM teaching narratives

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Abstract

The general objective of this overall work is to propose a methodology for the creation of language-neutral multimedia materials (without audio or text), which can be directly embedded in STEM courses in any language. The overall design of this project was discussed in [1].

The design was based on four stages: 1) a very explicit design of the course, mainly on the dependence of the concepts, using Compendium, 2) the careful selection of icons for some key concepts, 3) the generation of short interrelated animations, which try to identify a suitable graphic language (with both formal syntax and semantics), 4) the proposal of metadata, some internal to each animation and other external, to interrelate them. The final export of this educational package would consist of animations and their metadata, which would help facilitate re-use, and embedding within other courses.

In this paper we focus on the third stage. In the types of short animations discussed, we detected two complementary vocabularies. The first one labels the intentionality of certain scenes: presentation of a formal definition, presentation of positive examples and negative examples. The second marks the dependence of the concepts and their construction process: for example, if one is a specialization of a previous one, or if you are graphically emphasizing the use of a universal or existential quantification at that point in the construction of the concept.

At this stage, as the ultimate goal, we hope to achieve a semi-automatic process of generating animations. From the definition of first order logic of a concept (or other less formal descriptions), through the graphic language that is being investigated. This is a goal to be achieved. But we trust that this contributes to the creation and reuse of materials in the STEM area beyond existing language barriers.
Keywords
OER, STEM, multimedia, multilingual, OMDoc, compendium

1. Introduction

Motivation. The first author teaches the course "Logic and Discrete Structures" at UNED (National University of Distance Education, Spain), as part of the first year of a Bachelor’s degree in Computer Engineering. There were 1200 students enrolled last year, when the course was chosen as the best rated amongst the degree offerings. Those surveyed especially valued the animations that explained the fundamentals of the subject.

The second author is a researcher with the Open Learning Network group at the Open University (OU). The common interest of both authors in producing and reusing Open Educational Resources (OER) (in line with [2]; [3] and [4]) suggested the possibility of translating the aforementioned course into an OER with the intention of placing it into the OU LabSpace in the OpenLearn OER repository.

The most complex task proved to be the reuse of the multimedia support: it showed a high degree of coupling between video, audio and inserted text. At this point it was agreed that the material should be produced from scratch: to facilitate future joint maintenance and as a case study of a more general investigation.

Assumptions. Direct reuse of multimedia resources, beyond language barriers, is our most general objective in this article. It is supposed to be a more feasible goal in the STEM areas for two reasons: there is an underlying common mathematical language and there is a long tradition of using very effective abstract diagrams.

It is also supposed that any improvement in the production of reusable media may be useful in the following three scenarios: the reissue of new OER, the exchange of educational packages between one institution and another and in editorial processes. The latter includes recent authoring facilities which enable the production of extremely enriched texts, perhaps in different languages, that can be self-published.

Context. Wikimedia Commons and OER Commons are two initiatives with the same goal of effective reuse. However, the results are not as generally reusable as they should be. There is a lack of an appreciably widespread interest in sharing multimedia resources universally. Many authors unnecessarily insert textual explanations because they cannot find a simple way to add them to contextual metadata. Might this be the result of a lack of interest, production strategies, tools or assessment of the potential benefits?

As a methodological reference, it is worth considering the evolution of events in accessibility issues. Initially there were only a few authors concerned with this problem. Results were produced on a
small scale and not very homogeneous. These contributions began to be compared and refined socially, to the extent that a detailed formalization of languages and strategies developed. Tools were based and built upon this formalization which now allows almost all authors the opportunity to produce accessible content without excessive effort.

2. Objectives and methodology

This paper presents two complementary objectives performed in parallel.

1. On the one hand, it aims to design resources that can be directly embeddable in English and Spanish versions of the aforementioned course, transferring annotations to contextual metadata. And this task is intended to be framed within a strategy and tools that can be easily used by an author who wants to develop specific private results, on a small scale without much effort.

2. On the other hand there are already various attempts at formalization from which graphical representations of knowledge could be built in a more easily shareable way. We present some of the clues that have been obtained in the resolution of the case study.

To reconcile these two objectives we suggest a four stage method based on simple tools (CompendiumLD [5], Keynote, Screenflow and an XML editor). The four steps proposed are intended to help refine the process while helping to decouple concepts, diagrams and animations. This approach can be used very loosely or as a framework for reflection on appropriate ontologies and graphical facilities.

3. Case study: results

In our edition of embeddable animations we have followed these four stages:

1. Construction of the dependency graph of statements

2. Assignment of icons to a number of conceptual nodes

3. Assignment of animations to a number of conceptual nodes

4. Exporting icons and animations as well as contextual and internal structures

3.1 Concept map
In a first approximation, the design of the dependency graph between concepts is not viewed as a strictly formalized task to be completed first. One can choose the focus and extent of the context, building a partial map. Figure 1 shows the first steps in defining one of these concept maps.

![Figure 1: Simplified partial concept map focused on a theorem](image)

We have usually focused on statements such as definitions or propositions, expanding those nodes with the previous concepts required. Furthermore, we have added other types of nodes: examples or counter examples, proofs or refutations, or nodes with proposed strategies or proposed activities.

The methodology of Concept Maps [6] is followed to construct these maps. The OMDoc [7] mathematical ontology serves as a reference for node types and relationships.

### 3.2 Icons

In this stage, diagrams are assigned to a number of selected statements-nodes. In the optimal cases, those are visual representations isomorphic to the theory explained. Then multiple definitions and propositions within the theory can be stated as relations amongst components of the diagram. And an amount of Diagrammatic Reasoning [8] can be performed. This was the case in terms of Venn diagrams (complement, union, intersection, …) in some parts of our course, and this is the case for diagrams shown in figure 2 (consequence, satisfiability, validity, …).

Most frequently, there is not an isomorphic framework for some groups of concepts. Although one loses the ability to reason diagrammatically, you can still use that abstract icon as a name, as an ideogram of the concept. This was the case in the classification of types of relations and functions.

As Compendium shows images assigned to nodes, instead of their respective textual names, a graph of related ideograms can be iteratively produced. This refinement can pursue the construction of ideograms as simply and concisely as possible (e.g. removing the quantifiers in figure 2), and ensuring that the graphical conventions stay homogeneous.
With some conventions, the definition of the ideogram of a concept could be built using the ideograms of the component concepts. This is the case in Figure 3, which represents the if-part of a theorem that relates consequence and unsatisfiability.

At this point, we suggest some possible outputs of this strategy:

1. allows navigation between concepts / diagrams, directly on the GUI or reusing Compendium XML export
2. enables an overview of graphical conventions used, allowing homogenization
3. allows the detection of nodes that should be expanded as animations
4. and finally, decouples concepts and their graphical representations; two authors could propose different sets of representations, which would be stored in different dictionaries following a strategy already used in the representation of symbols and content in OMDoc

3.3 Animations

In general, the procedure of the previous stage has a limited capacity for expression. Diagrams, if they include previous ones, can quickly become inefficiently complex. Though some of them could
be simplified, moving, bounding or emphasizing annotations to an implicit agreement with the reader, there still remains many complex definitions or propositions. All these still images are perfect candidates to be expanded as an animation.

1. Some of them explain and confirm the refined nemonic icon. The animations are used here as a means of backward explanation: you get the icon which you want to fix after going through several stages of explanation and reinforcement.

2. Some of them project the icons into more complex statements or activities, e.g. graphically posing some questions, if diagrammatic reasoning is possible.

An animation can include different kinds of resources. Typically, to bound a statement or fix a representation, examples and counterexamples are used. Alternatively proofs, or a suggested strategy. All these resources were considered as part of the previous common ontology. All of them could have been proposed at the icons level. We only need to design a graphical and homogeneous beginning mark for every type of these actions. These steps configure the structure of the animation to the highest level.

There is an inner structure. Here the actions are concise graphics labels or icons that serve to emphasize, to limit the uniqueness, ask a question, note that is universal the quantifier being evaluated or suggest that the drawback of an activity is that it uses a non injective function, among other examples.

Here is a second ontology consisting of warnings, aids and proposed actions. And again, selecting the corresponding graphic elements is decoupled from the conceptual description of the ontology: different communities of users can take different graphic conventions.

3.4 Publication

The proposed methodology allows the generation of packages of animations which are conceptual and graphically interrelated. The conceptual relationship, if a tool like Compendium is used, can be explicit as a collection of XML metadata. It is the joint export of resources and their descriptors which gives value to this production.

Even for personal use it is an organized way to maintain our own repository. Much more is possible if you want to publish and share resources. In this case, the full cycle should be considered: we must facilitate the search for these resources and the information needed to be reused in another cultural context.
4. Discussion

The discussion in this paper aligns with work focusing specifically on OER for the computer science discipline area ([9]; [10]; [11] and [12]). The language barrier does not seem to be a challenge for authors of multimedia resources. However, English-speaking institutions do not exploit directly the resources of other great cultural contexts. And the mere production in English does not always guarantee a universal understanding.

After the practical work undertaken and the review of existing technologies and theoretical frameworks, we believe that we can produce more significant results than those seen on the Web. It is feasible and not much more difficult to do. This will be especially true when a number of recommendations and proper tools are available.

This paper has been narrated from an author, top-down, perspective. In tandem, we consider the results in Mathematical Knowledge Management, especially around Omdoc, a solid foundation on which to hook these descriptions. The automatic generation of slides, as Omdoc provides from their formal documents, is an interesting approach. Moreover this approach would benefit if the animations could be finally produced by an automatic script, in accordance with dictionaries of graphical resources and actions.

5. References


