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I2Geo: a Web-Library of Interactive Geometry

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Abstract. This paper describes I2Geo, the platform of the Intergeo project enabling math educators throughout Europe to publicly share interactive geometry constructions. This cross-cultural web-based platform makes each resource, be it a construction, a scenario of use, or a complete course, referenceable, editable, and reviewable.

It is based on reusable tools, a fine grained ontology of mathematical concepts and skills, together with a description of educational pathways in Europe: together they allow cross-cultural searches. Following the patterns of open educational resources, anyone may participate and contribute, either by commenting, by adding constructions, or by reviewing the quality of a resource.

We describe the current platform's facilities and the technical foundation that are used and will be used for upcoming features as well as the challenges they solve which are quite common to the broader digital mathematical libraries.

Introduction

Interactive (or Dynamic) Geometry software systems are well known computer-based tools to support teaching of mathematics by means of personal explorations. Sharing Interactive Geometry *content* across various boundaries is the objective of the Intergeo project. The major ones are:

- **Cultural boundaries** isolating educators in the communities of their language or educational region. However, the core of Interactive Geometry is almost deprived of words and most Interactive Geometry constructions often need no linguistic understanding from an expert to be evaluated and can be translated in very little time.
- **Software boundaries** which make it almost impossible for users of one software system to use constructions from another system. Even though every software differs in its approaches, there are many common mathematical concepts that should be transferable easily.
- **Acceptance boundaries** stemming from the fact that any new method for teaching needs approval by teachers and governmental bodies. The content's quality has to be assessed in order to build confidence in it.

The Intergeo Project⁴ is tackling the problem of making these boundaries crossable so as to provide a digital library of Interactive Geometry constructions, enabling exchange between all parties. The Intergeo project is co-financed by the European Commission in the eContent*Plus* programme, and the European setup of the project is both a chance and a challenge. The diversity of languages, dialects, educational systems and legal restrictions makes it necessary to pay particular attention to problems arising from these cultural barriers. At the same time, the richness of these different contexts can help to improve mathematics education everywhere. This work is done by curriculum experts which bring their mathematical insight to encode a map of the mathematical topics and competencies.

As for educational content, the project is aiming at the openly-licensed corpus that is becoming more and more available. The default license for content on the platform is of create-commons share-alike type, so these educational resources can be matured on the long term by the contribution of multiple individuals who:

- upload their educational resources on the Intergeo platform and annotate them with pedagogical metadata that will help to identify their content,
- comment on resources,
- provide quality reviews for resources,
- make enhancements to resources.

A few characteristics of the platform are needed for such actions to happen among people whose only contact is the resource under consideration: the resources need to be directly accessible, they need to be exchangeable between different formats, their annotations needs to be multilingual, and reviews need to be attributable, acceptable and shareable across cultures.

This paper presents I2Geo, the Intergeo platform which is being developed and used in the Intergeo project, it follows on the vision of [1] and the outline of [2].

1 The Intergeo Project in Short

The Intergeo consortium consists of experts on Interactive Geometry from all over Europe, with a team of eight universities and research institutes and two companies dealing with mathematics in education, spanning six countries.⁵

The project is open to external partners with all levels of involvement. The most involved ones having access to internal documents and discussions are *Associate Partners*, of which there are 35 so far, both individual experts and

⁴ See <http://inter2geo.eu> for the project web site.

⁵ University of Education Schwäbisch Gmünd (Germany), Université Montpellier II (France), German Research Center for Artificial Intelligence, Saarbrücken (Germany), Cabrilog SAS, Grenoble (France), University of Bayreuth (Germany), Université du Luxembourg, University of Cantabria, Santander, (Spain), TU Eindhoven, (The Netherlands), Maths for More, Barcelona, (Spain), University of South Bohemia Ceske Budejovice, (Czech Republic)

institutions, covering another 13 countries and many more software systems than those already developed by the consortium.⁶ This is particularly important for the extra effort to encode curricula of all European educational systems and to annotate resources with meta-data. Also, the partners identified almost 9 000 resources that can be contributed by external partners, adding even more content to the substantial amount of approximately 3 000 resources contributed by the consortium, covering all levels and topics of mathematics education.

Although most content is addressed to secondary math teachers, because that is where the bulk of our target users are, the project supports and contains much more sophisticated content, a wealth of resources coming from teaching and research at university level.

These resources are being collected on the I2Geo platform,⁷ which we will describe in the remainder of this paper. More basic information on the project is available on its website and in [2].

I2Geo is based on the web platform Curriki, with the addition of several tools tailored to our needs, that are platform independent and made available to the wider community. We believe they provide paradigms, concepts and tools that are interesting for other Digital Mathematical Libraries. They consist in the rich and fine grained GeoSkill ontology, together with an ontology browser GeoSkill TextBox, the curriculum fragments annotator, the Quality Evaluation Framework and the multilingual search engine, that we will describe in the following sections.

2 The Curriki Web Platform, a Basis for I2Geo

Curriki is a web server project and company which started under the name Global Education Learning Community.⁸ The choice of Curriki has been that of a web-server that is highly tuned for the usage of our target audience, educators which are sometimes little technically savvy, together with a proven scalability.

Adapting Curriki to the special needs of Intergeo turned out to be a non-trivial task, as it already features a highly complex system architecture and rich feature set. That work is ongoing and tending to a satisfactory stage along with I2Geo-particular extensions.

Curriki is considered as a digital library where content can be easily searched for and referenced together with a collaborative space where content can be adjusted, modified and reviewed.

As a first fundamental ingredient of a community platform, Curriki supports user-profiles and personal blogs. Registration is granted to anyone with a valid email address; registered users can contribute right away. This seems to run the risk of spam but surprisingly, although registration can be activated by

⁶ The consortium members are authors or maintainers of Cabri II Plus/Cabri Junior/Cabri 3D, Cinderella, GeoGebra, GEONExT, Geoplan/Geospace, TracenPoche, and WIRIS.

⁷ <http://i2geo.net>

⁸ The Curriki web-server is at <http://www.curriki.org/> and its software is documented at <http://curriki.xwiki.org/>.

spam-bots, content and blog contribution can only be done with a live browser. To our experience, the spam-bot created users never reach the point of posting content.

The user profiles are essential ingredients for a social activity provided by *groups* which share a forum and a collection of resources and documents behind a common URL. The user profiles are also essential in promotional actions; for example to present *featured resources*, or simply to present who contributed a given resource.

Curriki organizes the educational materials being shared in *resources* or *assets*, each having their own URL which resembles the original title. Thus, as is best practice on the web [3] and in emerging digital libraries such as [4], the assets are not only internal elements of a library catalog but take part to the whole web infrastructure:

- Links to assets can be posted anywhere else on the web: this includes blogs reporting opinions about assets and links in public communications; these links are the cornerstone of the Web 2.0's abilities [5], for example to rank pages in a global web search engine,
- The URLs can be used in bookmarks and the history of the web browser, for a valuation of the resources later in time, allowing a user to easily come back to this resource, simply typing words of the title in his location bar, and
- Links to assets can be transported per email and other communication facilities.

The display of a resource is, thus far, mostly a view of its metadata: the authors, the topics, the levels, the summary of quality as can be seen in Fig. 1. For some types a more elaborate preview is possible (e.g. the wiki-page types, the picture types, and, as we shall see below, soon the interactive geometry types).

The set of types of resources of Curriki is relatively rich, ranging from desktop documents to simple web-links and including on-site-edited videos, as well as wiki-pages; each has special services attached to it to enable upload, view, or edition. Resources, if the user permits it, can be edited or copied by any other user, thus fostering re-use and enhancement of quality. This is stimulated by a public review system described below.

An important type is that of resource-collection, which support users' management, for example to indicate the choices made for a particular task.

Metadata annotations of resources is done along a classical metadata schema. However, topics' annotations in Curriki are done as checkboxes in a tree of broad educational topics (such as *Social Studies* or *Geometry*), which is unsuitable for the fine grained topic infrastructure needed for Intergeo, as presented below. Similarly, educational levels are given in terms of students' age, while Intergeo refers to a grade level determined by the various curricula.

Resources' life are tracked in RSS feeds which can be focussed by groups or can be presented in web-browsers. The ability to see the history of actions is important for a living community which needs to be aware of its development.

The screenshot displays the I2Geo website interface. At the top, the logo 'I2G INTERGEO' is on the left, and the text 'Interoperable Interactive Geometry for Europe' is on the right. Below the logo is a navigation menu with options like 'HOME', 'FIND', 'CONTRIBUTE', 'CONNECT', 'HELP', and 'INTERGEO PROJECT'. A search bar is located on the right side of the header. The main content area features a sidebar with 'TABLE OF CONTENTS' and 'SPONSORS'. The central part of the page shows a resource titled 'TVARY VZNIKLE Z PÚLKRUŽNICE' (Shapes arising from semicircles). The resource includes a description in Czech, a list of 'Trained Topics and Competencies' (reflection, transformation), and 'Educational Levels'. A small image of a Cabri construction is visible, along with a 'FIG' icon. The page also shows user information, including the author's name 'Jiří Vaniček' and the last updated date '04/27/03'. At the bottom, there are links for 'Privacy Policy', 'Help', 'Contact Us', and 'All content licensed Creative Commons'. The footer contains logos for 'I2G', 'eContent Plus', and 'Creative Commons'.

Fig. 1: A very simple resource, a Cabri construction, in Czech, and its annotations within I2Geo for an English speaking user.

3 Cross-Curriculum Annotations and Search

Sharing mathematical resources should be possible independently of the language and regional differences. We investigated methods to annotate and to search with fine-grained mathematical topics and competencies even if the resources are in different languages.

Access via fine-grained topics and competencies is necessary, because, on the one hand, only fine-grained topical information allows to retrieve a precise resource, somewhat independently of its context, or its original language, and of its possible word constituents, and, on the other hand, the language of competencies is growing in usage and recommendations: most text-books now display them, and most curriculum standards are expressed in this way, so teachers have to be able to find suitable resources not by content, but by competency.

A scenario to be supported would be a teacher of Germany, looking for interactive explorations and exercises relating to the competency of constructing perpendicular bisectors. He should be able to search using terms like *Mittelsenkrechte* (perpendicular bisector) and *Strecke*, as well as *konstruieren* (construct), and find all matching contributions, even those of French or Spanish teachers. Moreover, he should be able to easily designate that competency and topic. For German, with the word *Mittelsenkrechte* or for French, with the word *médiatrice*, this is relatively easy with normal text-based search tools, but it fails

in English where the query *perpendicular bisector* may match two words in a text which is not related to the concept. We see, thus, that a more elaborate method than plain-text retrieval is needed: to allow users (both at query and annotation time) to designate the concepts they mean and for internationalization.

The need for **multilingual mathematical** search is very common and has been noted in [4]: important parts of mathematical literature are in languages different than English. The need for **disambiguation** is also very common as has been noted by [6] indicating that *algebraic K-theory* (a part of mathematics) should not be mistaken with *differential K theory* (a part of sociology): the word Riemann should ask for disambiguation between the *Riemann integral* and the *Riemann tensor* which are fully different concepts; similarly the word *instanton* should ask any contributor and searcher to disambiguate between a *Yang-Mills instanton*, a *gravitational instanton* (which are two fully different concepts) or a *caloron* (which is a particular type of Yang-Mills instanton).

Our approach is based on an ontology of mathematical topics which collects topics in a simple taxonomy and competencies as a composite of a verb (a *cognitive process* in the original parlance of [7]) and a set of topics. Examples of a topic include parallelogram or quartile while an example of competency could be apply proportionality constant to real world problems. These ontology nodes are web-browsable; online readers of this article are able to click on the text in sans-serif fonts such as that of the competency or topics just mentioned. The elements of the ontology are enriched with textual properties describing how they are named, whether commonly, un-commonly, rarely, or as an error.⁹

The designation process is enabled by an auto-completion paradigm: the users type a few words of the competency or topic they wish to designate and possible completions are listed, ranked by best matches, along with type information. The ranking is based on the coverage of the input: if the text being input thus far contains all the significant words of the name of the node, a much greater score is given; the score is also influenced by the commonality of the name. Notice that multi-word keywords can be matched, unlike many other existing solutions. The designation is used in the annotation process, as depicted in figure 2: at this stage, the users should provide the trained topics and competencies as well as educational level they see most fit for the resource being catalogued.

The search tool provided by the platform also makes use of this designation mechanism, but it also allows for text inputs to be matched as plain text-queries. The search tool then searches all the resources that are annotated with the given topic or competency, or the given text fragment. Unless an exact query is desired, the search tool will also perform query expansion: For a text query, it will try to *recognize entities* by a process similar to that of the designation above; it will keep only the three best matching tokens. For a competency query, it will expand to a query for the topics of that competency and maybe their parents

⁹ More information about the GeoSkills ontology, how it can be accessed and enriched, is at <http://i2geo.net/xwiki/bin/view/About/GeoSkills>



Fig. 2: Annotating a resource, step 2: topics annotation.

and children, and for a topic query, it will expand to a query for the children topics; finally, it will boost results with a better review score.

This search tool is accessible from the platform at <http://i2geo.net/>. An example search result is depicted in Fig. 3.

4 Internationalization of I2Geo

The Intergeo project's aim is to cover most European countries by the end of 2010. That means, among others, that the platform should be available in all official languages. There are three dimensions to this internationalization:

User-Interface Translation: The internationalization of the platforms' user-interface messages is done by the team of translators, both project partners and volunteers,¹⁰ who translate all phrases used. **Document Translations:** The same translators' generally also translate other documents of the platform which include, the help pages describing mature features of the platforms, and the project documentation of Intergeo. **Curriculum Encoding:** The last facet of internationalization is that of the enrichment of the GeoSkills ontology described in Sec. 3: it involves, first, to translate and add names to the existing competencies and topics in the target language (the *curriculum translator* role), then to add the competencies and topics not yet found, and finally to hyperlink

¹⁰ See <http://translators.i2geo.net/>.

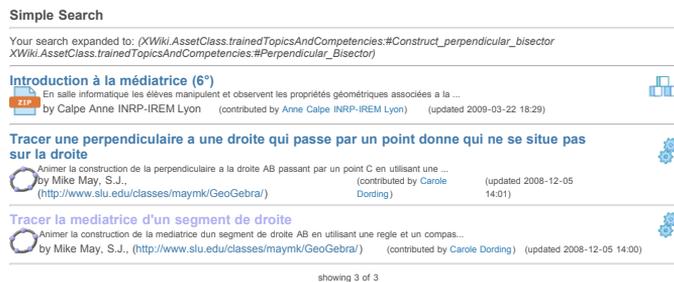


Fig. 3: Exemplary search result for the construction of perpendicular bisector

texts representing the curriculum standard with the links to the relevant nodes.¹¹

Thus far, Intergeo can count on translators and curriculum encoders for Spanish, French, German, Dutch, Czech, Portuguese, and Russian covering their countries as well as Latvia, and Slovakia.

5 Making Resources Visible and Acceptable

Providing educational resources is not enough for teachers to use them. Teachers have neither time nor self-confidence to assess the quality of a resource by themselves; most of them rely on suggestions made by colleagues they trust who used the resource and liked it, to consider it as acceptable for use. The Intergeo project aims at pushing further this **acceptance boundary** by providing a *quality framework* and an *editorial process* that transpose the existing practises of *peer evaluation* and *suggestions* to our platform. The community involved is global and multi-cultural, so it is a challenge to make it as personal as the day-to-day community of colleagues.

Quality Framework

One of the main objectives of Quality Evaluation is to raise the level of confidence of teachers in using Interactive Geometry: They will know how many teachers before them have ventured into teaching with a given resource and how they rate it.

The teachers themselves are at the same time *users* and *reviewers* of the content. The Intergeo project bootstraps this process by organizing evaluations through experts, but the sustainability of the project relies on the fact that these reviews are deemed useful enough by the users that they will actually give massive feedback. Therefore, the reviews have to be easy to take, thorough, multilingual, useful for ranking purposes and for improvement purposes, all at the same time.

This apparent contradiction between a simple and a thorough questionnaire was solved by providing users with a *foldable questionnaire* (see Fig. 4): All issues were categorized

REVIEW 11 FOR SOMME DES ANGLES D'UN TRIANGLE

Review title:

Global comment:
 It's a beautiful visual dynamic diagram. But a lot of information is missing for a relevant use in the classroom. What are the mathematical reasonings expected by the pupils? How the teacher is supposed to use it?

Review filed on 2009/01/16 18:49 by Soury Lavergne. ☆☆☆

Educational levels:

Radio buttons: more on the left side to say that I don't agree, more on the right side to say that I agree

I found easily the resource, the audience, competencies and themes are adequate
 The theme is the one I was looking for
 The mathematical prerequisites are the one I want
 Technical prerequisites are adequate
 Trained competencies are adequate and complete
 Objectives are stated and clear
 Proposed implementation (classroom, beamer, individual work...) is suitable
 The duration is stated and appropriate

Comments:
 No precise objectives for the use of the diagram in classroom are given. A prerequisite seems to be symmetry?

The files are technically sound and easy to open
 The content is mathematically sound and usable in the classroom
 Translation of the mathematical activity into interactive geometry is coherent
 In this resource, Interactive Geometry adds value to the learning experience
 This activity helps me teach mathematics
 I know how to set my class for this activity
 I found easily a way to use this activity in my curriculum progression

Fig. 4: A Quality Review within I2Geo for an English speaking user.

¹¹ The team of curriculum encoders is not exactly the team of translators since it is more pedagogy oriented. See <http://curriculum.i2geo.net/>.

into 8 main themes, themselves subdivided into less than 10 more precise questions. Answers can be given as a whole to assess the theme by itself, or more precisely, for a deeper analysis, by answering the sub-questions. If the precise questions are answered, then the weight of the more in-depth review is higher for final average rating of the resource than for the ones where only the major questions were answered.

All ratings are on a Likert scale ranging between “agree” and “disagree.” Although it is possible to add written comments, reviewers are encouraged to use the numerical rating only for the support of multilingual aspects.

A *personalized average mark* for each resource will be computed, based on each user’s profile. Every user can assign weights to each of the 8 main themes. So it is possible for a user to put an emphasis on the didactical aspects, the ease-of-use of in the classroom, or the additional explanations, depending on his or her prior experience.

The questionnaire has been repeatedly assessed by the Institut National de Recherche Pédagogique (INRP) in Lyon, France[8,9], and it is available on the platform in several languages.

Editorial Processes

The score of a resource is also used for editorial purposes. Every author is able to use the review data to identify weak (or strong) parts of his or her contribution, and can act upon it, or allow others to do it, by assigning a share-alike-license to the resource.

The evaluation can be used as well to make resources more visible by showcasing the good resources up on the front pages through hall of fames and editorial work. This can also stimulate online communities of practice. Currently, this selection is done manually but automating that process is expected.

6 Software Availability

I2Geo is an open-source platform written in the Java language, with parts written in Velocity and Groovy. Its installation instructions, explanations for the technology names below, as well as its download URLs are published in [10]. It consists of the following components: Curriki, and the UI tunings, an XWiki application, under the Gnu General Public License; the quality framework based on XWiki, available under the Lesser General Public License; SearchI2G, the search tool as well as the auto-completion facility, based on Apache Lucene and the Google Web Toolkit and available under the Apache Public License; CompEd, the competency editor supporting the curriculum encoders, an AppFuse based application available under the Apache Public License.

This pack of web-applications is deployed on <http://i2geo.net/> where early users have already contributed and report the issues they encounter. The first platform public visibility, in October 2008, has been relatively difficult with

many performance issues and several broken features. Progressively, many have been fixed and the tunings are almost concluded with performance being acceptable. The plain-text search engine, thus far, is not satisfactory for many just as the lack of topic-based browsing, all dependent on the cross-curriculum-search. The richness of the user-interface of Curriki, sometimes offering too much features or too much desktop-like appearance has discouraged several users; we hope the recent performance enhancements to support their return.

7 Comparable Approaches

Many platforms emerge nowadays on the web to serve teachers. Some provide mechanisms that enable teachers to share educational resources in an open fashion. Here we do not cover open educational resources like MatheVital (<http://www.mathe-vital.de>) that do not support contribution of content from users or in-site recollection; similarly, we do not consider general-purpose tools such as Wikipedia (<http://wikipedia.org>).

Our search engine approach uses the same basic techniques as classical digital mathematics libraries such as [11,12] but the focus on searching for formulč is absent. Instead we focus on curriculum based system, following the categorization wishes expressed in [13]. We claim that our search approach does allow the users to solve the conceptual ambiguities.

Among others, the Merlot **learning object repository** is most well-known for this objective¹² This repository, just as most others, tend to be unable to provide fine-grained topical or educational-level information. As a result, we believe, most of the times, the normal text search is used. We have seen above that this is insufficient for such searching purposes as *triangle rectangle*.

Finally, several **commercial enterprises** at offering content (for a fee) to teachers **based on alignment on curriculum standards** have emerged, among others the initiative Curriculum Online of the British Educational Communications and Technology Agency,¹³ which is now out of service, and the just launched Sketchpad LessonLink.¹⁴ To our knowledge, these enterprises are based on the direct attachment of resources to curriculum standards' fragments. This is somewhat livable for a limited curriculum intent such as that of England and Wales or those of the United States of America but is clearly not appropriate for the numerous educational regions of Europe (11 in Spain, 16 in Germany, 23 in Switzerland, . . .). Another very strong difference is in the authorability and availability: while the content of SketchPad LessonLink is usually not publically available and is only authored by its editorial teams, I2Geo's content is public by default with the web-browsers' URLs as a permanent link, and can be authored by anyone with an email address. The differences go as deep as the underlying technology.

¹² The Merlot learning object repository is at <http://merlot.org/>.

¹³ <http://www.curriculumonline.gov.uk/>

¹⁴ <http://www.keypress.com/x22318.xml>

8 Outlook and Conclusion

The Intergeo platform I2Geo has been in beta testing for a few months now and the feedback from experimental users is continuously informing further development following the *eternal beta* of [5].

The further technical development of the platform has mainly to achieve the goal of sustainability. We believe that it will contain enough attractive content for teachers, but this is not a guarantee for success. In order to promote sustainability, we try to grow the community into an online social network around the platform. Several venues are considered, taking ideas from other available social networks. We present two of these ideas below then two further challenges.

Kharma points to Weight Reviews The public aspect of the review system is both a valuable openness and a danger for spamming, especially since they boost the search result score. We intend to investigate the maintenance of a hidden *karma-value* for each user, fed by actions deemed positive on the platform. These karma points would weight in the balance when computing average marks of resources according to quality evaluations. Special users like groups, or didactical researchers, would automatically get high karma from the beginning.

This way, we think vandalism will be minimal and on the contrary people will value their input, feeling part of a larger community and priding in their building status. Such a model of karma has been used in many other platforms; one of the known successful one is that of Freshmeat.net which Y. Benkler has described in [14].

Fans and friends, leaders and followers, social distance and correlation The motto here is the web 2.0 slogan “the users know best”. That is to say let them build a collective experience, based on networks, whether consciously or automatically built, and use it to adjust ranking and promote visibility.

As we have described above, several aspects of the life of Intergeo resources and groups are accessible over RSS streams. This is a first step in the direction of entering external servers that syndicate. We intend to apply this further, for example so that some facets of Intergeo activity are perceivable from social networks such as the Facebook or Twitter environments. On the I2Geo platform itself, social flags like “friends” could be used in order for people with common interests to share more closely their experience. The friendship, if in moderate quantity, can be honoured at query expansion by boosting resources reviewed positively by friends. The automatic correlation between resources use and through “friends” use could in the long term be taken into account in an *amazon-like* fashion: “the users who taught with this resource used this other resource as well”.

Too many surprises in search results? Search results are a crucial part of the value of the I2Geo platform. This is the reason it has been the result of such an elaboration. Among the tunings that need to be addressed for its acceptance is the precision and recall obtained by the search tool. A first approach is to allow

three levels of query expansion, the fuzziest creating potentially the biggest noise in search results. Showing the score obtained for a match may also be an indicator that the users can receive and that is used.

In general, having mathematical semantics yielding, for example, the hierarchy of topics seems to be the right thing; the search tools shows intelligent when it suggests *integer numbers* while *negative* was input. However, there may be times when this intelligence is misunderstood. We intend to use search highlighting to explain the matches and maybe also allow the users to see the expanded queries in a readable way.

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