INTEROPERABLE INTERACTIVE GEOMETRY FOR EUROPE – FIRST TECHNOLOGICAL AND EDUCATIONAL RESULTS AND FUTURE CHALLENGES OF THE INTERGEO PROJECT

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*Abstract: In this overview article we describe the manifold achievements and challenges of Intergeo[1], a project co-funded within the eContent*plus *programme[2] of the European Union.*

THE INTERGEO PROJECT

The Intergeo project started in October 2007 and will be funded until September 2010. Its main concern is the propagation of Interactive or Dynamic Geometry Software.

Goals

Interactive Geometry is a way to improve mathematics education by using computers and Dynamic Geometry Software (DGS) and there are many advantages in comparison to “classical” geometry without DGS. Figures can e.g. be easily manipulated [see e.g. Roth 2008] and thus virtually be brought to life, comparable to what movies mean to images or to what interactive computer games mean to motion pictures.

It is therefore not amazing that Interactive Geometry obtains more and more attention in many educational institutions. Around 25 per cent of the countries within the EU refer explicitly to DGS in their national curricula or guidelines and roughly 40 per cent refer to ICT in general. And although the remaining countries do not mention ICT, some of them recommend the use of DGS in schools [Hendriks et al. 2008].

Still, the adoption of DGS at school is often difficult. Despite the fact that a lot of DGS class material exists, Interactive Geometry is still not used in classrooms regularly. Many teachers do not seem to know about the new possibilities, or they do not have access to the software and/or resources.

The Intergeo Project has identified the three following major barriers, that have a negative impact on the use of Interactive Geometry in classrooms [Intergeo Project 2007]:

- Missing search facilities

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[1] http://inter2geo.eu
[2] http://ec.europa.eu/information_society/activities/econtentplus/index_en.htm

Though many resources exist, there remains the problem of finding and accessing them. If the files were put on the internet by their developers, they are virtually scattered all over the web and it is extremely hard to retrieve them by using search engines like Google.

- Lack of interoperability
  There are many different programmes for Interactive Geometry on the market and each software has its own proprietary file format. Thus, finding a file does not automatically mean that it can be used – it must be a file for the specific software that is used.

- Missing quality information
  And even if a teacher finds a file and the file works with her DGS, it may still be unsuitable for the use in class due to a lack of quality. Lacking quality can be software-sided in the way the figures are constructed or missing (or even wrong) mathematical background.

The aims of Intergeo are to dispose of the problems stated. In other words, Intergeo will

- enable users to easily find the resources they are looking for,
- provide the materials in a format that can be used with different DGS systems, and
- ensure classroom quality.

All three facets will be dealt with in the following chapters in extenso.

Furthermore, Intergeo attends to a topic that is mostly neglected but of high importance nonetheless: the question of copyright.

Consortium

The Intergeo Consortium, the founding partners of the Project, assembles software producers, mathematicians, and mathematics educators: Pädagogische Hochschule Schwäbisch Gmünd (D), Université Montpellier II (F). Deutsches Forschungszentrum für künstliche Intelligenz DFKI (D), Cabrilog S.A.S. (F), Universität Bayreuth (D), Université du Luxembourg (LUX), Universidad de Cantabria (ES), TU Eindhoven (NL), Maths for More (ES), and Jihočeská Univerzita v Českých Budějovicích (CZ). As the common interest of all partners is the propagation of sensible use of Interactive Geometry in the classroom, it was possible to collect both commercial, semi-commercial and free software packages. This is one of the key ingredients of the project: By building upon the joint knowledge and expertise of all parties, we hope to be able to address the needs of the teaching community.

Participation of External Partners

The participation of External Partners, as Associate Partners, Country Representatives, and User Representatives justifies the basis for assuring the sustainability of the projects' goals as mentioned above. Furthermore, gathering partners, as software developers, teachers, and persons at school administration level enables the development of a Europe-wide network that is indispensable for obtaining the projects' major achievements.

Since the project start in October 2007, several key actors in interactive geometry throughout Europe, including software producers, mathematics educators, governmental bodies, and innovative users that can provide additional content or serve as test users for the first content iterations were acquired.

Associate Partners

The role of Associate Partners implicates a variety of tasks and expectations, as the adoption of the common file format for their software, the provision of significant content to the Project, the development of ontologies, and the conduction of classroom tests. The project could successfully find several important Associate Partners, see [Intergeo Project 2008] and the following table.

Table: List of Associate Partners

Nr.	Country	Name	Nr.	Country	Name
1	Austria / USA	Markus Hohenwarter (GeoGebra)	**15**	Germany	Andreas Göbel (Archimedes Geo3D)
2	Brazil	Leônidas de Oliveira Brandão (iGeom)	**16**	Germany	Reinhard Oldenburg
3	Canada / Spain	Philippe R. Richard, Josep Maria Fortuny (geogebraTUTOR)	**17**	Germany	Andreas Meier
4	Canada	Jérémie Farret (3D Geom)	**18**	Germany	Roland Mechling (DynaGeo)
5	Croatia	Sime Suljic (Normala)	**19**	Italy	Giovanni Artico (CRDM)
6	France	Cyrille Desmoulins	**20**	Luxembourg	Daniel Weiler
7	France	Odile Bénassy (OFSET)	**21**	México	Julio Prado Saavedra (GeoDin)
8	France	François Pirsch (JMath3D)	**22**	Portugal	Arsélio Martins
9	France	The Sesamath association	**23**	Portugal	José Francisco Rodrigues (CMAF)
10	France	EducTice - INRP / Luc Trouche	**24**	Slovakia	Dusan Vallo
11	France	IUFM - Jacques Gressier (Geometrix)	**25**	United Kingdom	Albert Baeumel
12	Germany	Jürgen Roth (Universität Würzburg)	**26**	United Kingdom	Nicolas van Labeke (Calques 3D)
13	Germany	Heinz Schumann	**27**	United States	Joshua Marks (Curriki)
14	Germany	René Grothmann (C.a.R. / Z.u.L.)			

Country Representatives

For each EU country a Country Representative serves as a contact person in their respective country. They come from ministries of education, preferably, and enable the Project to easily contact the relevant persons at school administration level. Based on these contacts, the project develops ways to map curricula into the ontology for geometry that suits all countries of the EU. The project could successfully find several Country Representatives, and a list is available at [Intergeo Project 2008].

User Representatives

User Representatives, as teachers and software partners, build the basis for the sustainability of the project. They are a contact point with their associations, in order to support the relationship with potential Intergeo-users [Intergeo Project 2008].

- Selected teachers ease experimentations in the classroom of educational content gathered by the project, promote the use of the Intergeo-platform and the philosophy of resource sharing and quality control.
- Selected Software-partners promote the uploading of content to the Intergeo-platform.

Among others, the selection of external partners will be performed at several local user meetings during the project period. The local user meetings have a central role in gathering the community of practice. They intend to help providing a complete European coverage:

- The Local User Meetings present Intergeo to the users: The need of a common file format for interoperability, the need of a web platform to share resources, the need of the ontology and the curriculum mapping to share resources across all European countries.
- The Local User Meetings are a good way to reach power users and engage them into the project to improve the projects' dissemination.
- Local User Meetings identify suitable schools for the Quality Assessment.

MAJOR ACHIEVEMENTS

Content Collection

The consortium promised to offer a significant amount of content for use in the database. Before the project started in Oct. 2007 we identified more than 3000 interactive resources to be used. All these and more[3] have been collected through the Intergeo platform by September 2008, first as *traces*, and now being converted to real assets that are searchable and tagged with meta-data. The available content ranges through all ages and educational levels, and also mathematical topics and competences. See http://i2geo.net to access and use the content.

Copyright/Licence issues

A major issue with content re-use and exchange is the handling of intellectual property rights. This affects not only the copying of resources, but also the modification and the classroom use. Without being able to process the data, it is also impossible to offer the added value of cross-curriculum search, for example.

Thus, all content that is added to the Intergeo portal has a clear license, usually of the creative commons type allowing for modification and free (non-commercial) use. See http://creativecommons.org for details.

Theoretical Foundation For Cross-Curriculum Categorization and Search

Interactive geometry has one quality that makes it very particular among learning resources: it is often multilingual. This led us naturally to propose a search tool for

[3] On September 30th, 2008, there was a total amount of 3525 traces available.

interactive geometry resources that is not just a textual search engine but a *cross curriculum* search engine.

A simple scenario can explain the objective of cross-curriculum search: a teacher in Spain contributes a Cabri construction which is about the intercepting lines theorem (the *Teorema de Tales*) and measuring segment lengths; a teacher in Scotland looks for a construction which speaks about the *enlargement* transformation, *segment lengths*, and the competency to *recognize proportionalities*. They should match: the Scottish teacher should find the Cabri construction of the Spanish teacher (and be able to convert it to his preferred geometry system). No current retrieval system can afford such a matching process: there is no common word between the annotation and the query.

For cross-curriculum matching to work, a language of annotations is needed that encompasses the concepts of all curriculum standards and that relates them. Careful observation of the current curriculum standards (see [Laborde et al. 2008]) has shown that topics, expressed as a hierarchy, and competencies are the two main type of ingredients that are needed. To this end the Intergeo project has built an ontology of topics, competencies, and educational levels called GeoSkills. This OWL ontology [McGuinness et al. 2004] has been structured and is now being populated by a systematic walk through the national curriculum standards; a report of this encoding is at [Laborde et al. 2008]; completeness for several school-years has been reached in French, English, and Spanish curriculum standards. Because the edition of an ontology using a generic tool can be difficult, a dedicated web-based tool is under work which will make it possible for the complete German, Spanish, Czech, and Dutch curriculum standards to be encoded by the Intergeo partners and its associates.

For the match to happen, the input of topics or competencies has to be cared for. We use the auto-completion paradigm for this purpose: the (textual) names of each topic and competency are searched for in this process and the user can thus choose the appropriate node with sufficient evidence, maybe browsing a presentation of the topics and competencies. An alternative approach proposed is to browse curriculum standards, being documents that teachers potentially know well, in order to click a paragraph to choose the underlying topics and competencies.

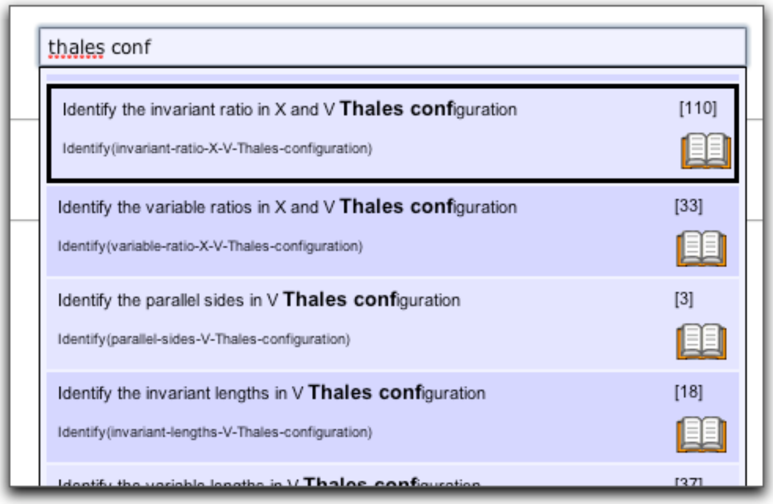

Figure 1: The skills textbox

Quality Assessment Framework

A Quality Assessment Framework for the Intergeo project was set up based on a questionnaire filled freely by the teachers themselves [Mercat et al. 2008]. This assessment has two different aims:

- To rank the resources so that, in response to a query, "good" resources are ranked before "bad" resources, at equal relevance with respect to the query.
- To help improve resources by identifying criteria to work upon in order for the author to revise his resource according to the user's input.

The questionnaire is both easy and deep; it can provide a light 2 minutes assessment as well as a deep pedagogical insight of the content. This is achieved by a top-down approach: The quick way just asks for 8 broad statements that can be answered on a scale from "I agree" to "I disagree":

- I found easily the resource, the audience, competencies and themes are adequate
- The figure is technically sound and easy to use
- The content is mathematically sound and usable in the classroom
- Interactivity is coherent and valid
- Interactive geometry adds value to the learning experience
- This activity helps me teach mathematics
- I know how to implement this activity
- I found easily a way to use this activity in my curriculum progression

These broad questions can be opened up by the reviewer to give more detailed feedback on issues of interest for him, such as "Dragging around, you can illustrate, identify or conjecture invariant properties" in the "Interactive geometry adds value to the learning experience" section.

Of course a thorough questionnaire is weighted more than a quick reply in the averaging of the different answers. The questionnaire is to be taken twice, as an a priori evaluation, before the actual course, and as an a posteriori evaluation, after the teaching has taken place. This second variant is being more weighted than the first one.

Different users are weighted differently as well: seasoned teachers with a lot of good activity, or recognised pedagogical experts, will have a high weight: their reviews are taken into account more than the average new user. Negative behaviour like steady bashing or eulogy will, on the contrary, lower user's weight. We are thinking as well about a social weight: teachers could flag some of their colleagues as "leaders", users whose past choices they liked, because they are teaching at the same level for example, and the weight of these leaders would increase.

The I2Geo Platform

The central place of exchange of interactive geometry constructions is a web-platform; the i2geo.net platform is becoming a server where anyone with interest to interactive geometry can come to search for it and to share it.

The i2geo.net platform is based on Curriki, an XWiki-extension tuned for the purpose of sharing learning resources: strong metadata scheme, quality monitoring system and self-regulated groups. Being based on a wiki platform, Curriki offers an online editing and inclusion facility and thus also makes collaborative content construction possible.

The i2geo platform has three major adaptations compared to the tools provided by Curriki: the search and annotation tools, the review system, and the support for interactive geometry media.

The i2geo search and annotation tool uses the GeoSkills ontology described above: this allows the trained topics and competencies, the required ones, and the educational levels to be all entered using the input methods described above (auto-completion and pick-from-document).

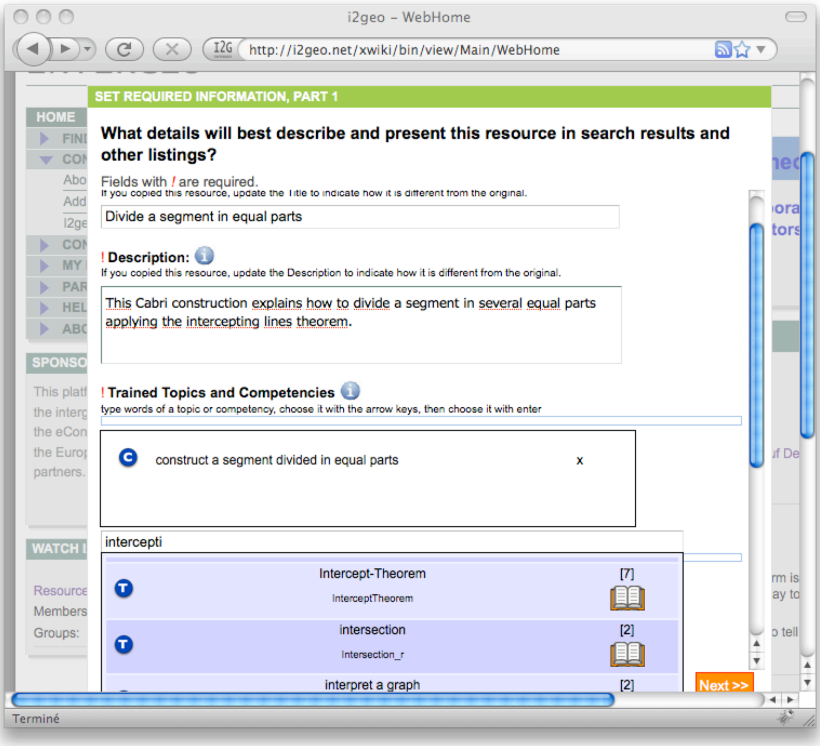

Figure 2: Editing metadata

Such elaborate methods are needed if one wants to honour the rich set of educational levels in Europe and the diversity of curriculum standards sketched in [Laborde et al. 2008].

The i2geo search tool uses the GeoSkills ontology as well: queries for any concept are generalized to neighbouring concepts which thus allows the match of the intercepting-lines-theorem when queried for the concept of enlargement.

The i2geo platform is under active development and can be experimented with on http://i2geo.net. Its current development focus is the input of metadata annotated resources and the review system described in the previous sections. The services specialized to the geometry resources, enabling easy upload, preview, and embedding of interactive geometry resources will be provided later.

A Common File Format

A wide variety of Dynamic Geometric Systems (DGS) exist nowadays. Before this project, each system used incompatible proprietary file formats to store its data. Thus, most of the DGS makers have joined the project to provide a common file format that will be adopted either in the core of the systems or just as a way to interchange content.

The Intergeo file format aims to be the convergence of the common features of the current DGS together with the vision of future developments and the opinion of external experts. Its final version based on modern technologies and planed to be extensible – to capture the flavour of the different DGS – could serve as a standard in the DGS industry.

The specification of the first version of the Intergeo file format has been released by the end of July as deliverable D3.3 [Hendricks et al. 2008] after intensive collaboration between DGS software developers and experts. At present, the file format is restricted to the geometry in the plane, although it does not seem difficult to extend it, in the future, to the space. Besides it specifies only a restricted subset of possible geometric elements, which however lead to an agreement on the structure and basic composition of the format.

The general framework was clear from the outset: to design a semantically rich format that could be interpreted by at least all DGS in the consortium. One main design decision in this respect consists of the choice of constructions, as opposed to constraints, because in general, it is very difficult to give any particular solution for a set of constraints. Besides constraints of a strictly classical geometric nature do not say anything about the dynamic behaviour of a figure. A natural way to shed light on both of these problems is a more precise specification of how the objects depend on each other, stipulating first which objects are free and then proceeding step by step. Such a specification is called a construction. This decision implies less interoperability with constraint-based systems, since some of their resources will not be encodable into this format. But it ensures that construction-based DGS – the majority of the existing systems – will be able to interpret the resources.

As stated in the Description of Work, OpenMath Content Dictionaries are used to specify the symbols – the main ingredients used to describe a construction – of the file format. The XML schema can be generated automatically with some knowledge of how the atoms are expressed in XML. The complete list of official symbols defined so far can be found at http://svn.activemath.org/intergeo/Drafts/Format/.

As soon as version 1 of the file format got more concrete, some software developers started to investigate its practical usage by integrating it (partially) into their software. It was possible to move simple content between several of the packages in the project. For more information on the file format we refer to [Hendriks et. al 2008], which also lists the relevant URLS to see the progress.

NEXT STEPS AND CHALLENGES

Metadata Collection

With the arrival of the first curriculum-aware beta version of the i2geo.net platform we are now able to attach metadata to the existing content. This includes information about the authors, but also about the intended audience for a resource, the skills and competences that can be acquired through the resource, the prerequisites, and, of course, the topic – categorized according to the ontology.

While some of this information can be extracted automatically, there is still need for a lot of manual intervention. At the same time, the curricula available on the platform have to be revised and extended to accommodate all the content.

Quality Testing

The partners in the Quality Assurance work package will conduct small-scale experimentations in the classroom during the period January-April 2009. Teachers, whether alone or in homogeneous teams, will

- Use the platform in order to identify content suitable for their course,
- First fill an a priori questionnaire,
- Teach the resource in the classroom,
- And finally report on its use by updating the a posteriori questionnaire.

We will have to agree on a modus operandi, recruit volunteers, especially among the teachers that were contacted during the users meetings, instruct them and have them conduct the experimentations.

Then these assessments will be analyzed. The analysis will be used to iteratively improve the quality assessment framework according to the users' feedback on usability and relevance of the different items and of the online platform.

It is a primary concern that all resources receive at least basic testing. Thus, we will check the overall coverage in the project and, if necessary, identify resources to be tested.

As the quality assessment primarily aims to make it possible to improve ranking and quality of the resources, we can use this as a performance indicator. For this, the changes in ranking due to the quality evaluation will be measured. Additionally, selected examples will be analysed in order to understand whether authors can infer improvements of their resources.

Via interviews with selected authors we try to understand how they perceived quality assessment and how we can improve its perception as positive, constructive and scientific more than negative, useless and personal.

In the final year of the project, mass scale experimentations will take place. More countries and more parts of the curriculum shall be covered.

File format

As for version 1 of the file format some decisions that should be made with the help of other developers of DGS have been postponed, those experts are invited to join the discussion and propose solutions or give remarks, see [Hendriks 2008]. Thus, substantial modifications of this specification are expected to solve all practical issues that might arise.

Better Visibility

The ultimate goal and a measure of success is the visibility of the Intergeo platform in Europe as a whole. After the first year was devoted to setting up the technical prerequisites and administrative processes, as well as clearly describing how we can measure and improve the standards for successful interactive resources, we can now offer a *usable* platform with substantial content. We now have to make the platform more visible and raise interest within the didactical community, the teachers, and the governments throughout Europe.

Today, the websites of the individual software packages from the project still have much more visits a day than the i2geo.net portal. So a first step will be to announce the portal on the websites of the software packages and on the websites of (associate) partners using banners and an i2g-compliance badge that shows the compatibility of the software with the i2g file format.

CONCLUSIONS AND CALL FOR PARTICIPATION

In this article, we can only highlight the basic structure of the project. We invite everybody to visit the project website at http://inter2geo.eu, submit their own content on http://i2geo.net, join as an Associate Partner or become a User or Country Representative.

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