

Graphical Interactive eAssessment in Surveying

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Key words: eLearning, Geoinformatics, Online Test, interactive questions.

SUMMARY

Subject matter of the research within the GIA project (Graphical Interactive Assessment) was the development of concepts and mechanisms for supporting the development and evaluation of online-questions. The main focus was set on graphical interactive questions.

A concept based on question templates was developed for this purpose. The there from resulting skeleton for each question templates is the base of the development within GIA. It has to be emphasized, that there are separate components for the graphical representation of the issue, for the description of the interaction as well as the definition of the routines needed for the automatic evaluation.

The technical objective within this research project was the development of a platform that provides a framework for the development and application of new graphical question templates. The developed GIA platform is running as a stable prototype and has been tested in varying scenarios.

ZUSAMMENFASSUNG

Gegenstand der Forschungsarbeiten des GIA-Projektes war die Entwicklung von Konzepten und Mechanismen welche die Erstellung und Auswertung von Online-Fragen mit Schwerpunkt auf graphisch interaktiven Fragestellungen unterstützen.

Hierzu wurde ein Konzept auf Basis von Fragentemplates entwickelt. Das hieraus resultierende Gerüst für Fragentemplates ist die Grundlage für die gesamte Entwicklung. Hervorzuheben sind hierbei die separaten Komponenten zur graphischen Darstellung der Sachverhalte, zur Beschreibung der Interaktion sowie zur Definition der Evaluierungsalgorithmen.

Die technologische Zielsetzung dieses Forschungsprojekts war die Entwicklung einer Plattform, die ein Rahmenwerk für die Entwicklung und Anwendung von neuen graphischen Fragentemplates darstellt. Die entwickelte GIA Plattform steht als stabiler Prototyp zur Verfügung und wurde in unterschiedlichen Szenarien getestet.

So wurden z.B für das Anwendungsgebiet Geoinformatik und Vermessung unterschiedliche Fragentemplates entwickelt und auf deren Basis Fragenblätter umgesetzt, welche im Studium Geoinformatik und Vermessung erprobt wurden.

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1. INTRODUCTION

This paper describes the results of the research project “Graphical Interactive Assessment” (GIA) which was conducted at the research institute “i3mainz”. The project focused on automatic generation and evaluation of online-tests with a focus on graphical interactive questions. The major application domain of the research is the higher education in Geoinformatics and Surveying at the University of Applied Sciences in Mainz. Special attention within the paper is drawn on the new approach for the authoring and automatic evaluation of graphics based questions by the means of new innovative templates.

2. MOTIVATION

Online assessment is widely accepted both for self-assessment and also as the basis for examinations. A good example demonstrating the success of online quizzes is the GIScience program (Veenendaal 2001). A well accepted example of a tool for online tests is “Webassign” (Brunsmann 1999), it has been in use e.g. since 1998 by the “Fern-Uni Hagen”, the most popular Open University in Germany. Advantages arising from the use of such online-testing systems for authors are e.g. the reusability of test questions and better statistical feedback (Natal 1998). Most recently a very renowned university in Berlin introduced the first online test for the examinations in the medical education. Even though its launch in February 2004 (Spiegel 2003) was not successful due to server problems, it showed already the openness towards this new technology in the educational sector.

A lot of the current existing E-Learning and assessment systems focus on single or multiple-choice questions (MCQ) with several answers and radio-buttons to select the correct one. The forefathers of computer based questions were designed like this, because MCQ are fast and easy to build – and can afterwards be corrected automatically. These types of questions seemed (and still seem) to be the ones that some teachers and professors in the educational sector prefer. To use these kinds of questionnaires saves time and cost, especially with large groups of learners. Moreover, faculties like medicine traditionally have long MCQ-tests where the students e.g. have to find the correct definitions or names of muscles. All this is very easy to verify, because the results are obvious. It should be noted that the pure application of MCQ is not undisputed – but the decision might be left to responsibility of the WBT author, or the responsible professor.

2.1 Requirements for the Surveying and Geoinformatics Community (SGC)

Online assessment in the Surveying and Geoinformatics Community (SGC) has specific requirements. The SGC deals in general with spatial data which is in most cases represented by 2D or 3D visualisation means. Under this light the traditional MCQ are unable to cover all the aspects which should be included in knowledge assessment. The following requirements

for graphical questionnaires in SGC are derived from the program of study "Geoinformatics and Surveying" at the University of Applied Sciences in Mainz:

- Graphical identification of single and multiple areas (e.g. used for photogrammetry)
- Determination of trajectories representing e.g. a traverse (surveying)
- Processing of raster graphics (digital image processing)
- Source Code workflow (programming courses)
- Planning of aerial flights (photogrammetry)
- Identification of objects in aerial images (photogrammetry)
- Simple GIS-functionality (geoinformatics)

Further consideration why graphical based questionnaires (GBQ) provide advantages compared to traditional MCQ were further discussed in (Böhm, Dietze 2004).

Nowadays there are already various types of graphical questions that are asked in computer-based tests. But mostly this has been done by the usage of Plug-Ins like Shockwave and Flash that allow questions with more graphical elements and interaction from the users. For example somebody is asked to drag an element to a specific position on an image. These questions show that there is a need for more interactivity and they are also a first step towards new concepts for GBQs.

Current solutions: A set of very powerful tools like e.g. the Macromedia Dreamweaver or the ToolBook Instructor allow building complex questionnaires with innovative and content dependent graphical questions. The development of those questionnaires still requires profound skills in the usage of these tools and a lot of time. The effort can thus be calculated similar to full regular WBT learning courses. Additional development is needed for the presentation of exam statistics to the professor and to the learner. Thus innovative knowledge assessment by the usage of modern graphics based questions is still an expensive mean.

3. THE NEW GIA APPROACH

The research performed within the GIA-project addresses the specific need for the SGC in order to overcome the current limitations by developing a solution that supports the processes of authoring questions and questionnaires, executing tests and evaluating them. This support is given by the use of adequate tools.

The GIA framework provides the following functionality:

- A web-based Editor for developing graphical interactive questions. It allows an author fast and easy building of these types of questions through the use of an extendable catalogue of question templates.
- A question-browser that enables the author to manage the questions within the database. It lists the existing questions sorted by topics and therefore allows an easy reuse of them.
- A new concept to store graphical elements from within these questions in a database including the procedure for the automatic verification of them.

- A question provision module that displays the questionnaires to the learner by combining the template and the question-text with the overall layout.
- An evaluation module on the server for an automatic verification of the completed questionnaire.

4. THE TEMPLATE CONCEPT

4.1 The Basic Components

The process of building graphical interactive questionnaires for the SGC is time-intensive for authors (see above). Thus one main objective of our investigations was to reduce this time exposure. The time for authoring a question should not exceed several minutes per question. The following approach was taken:

- The skeletal structures of numerous questions were analysed and generalised.
- The question-specific parts were extracted and classified in different templates, the so called “question-templates”.
- The general components in turn were integrated into the system.

These question-templates not only consist of the components for the authoring and presentation, but also of the routines for enabling an automatic evaluation.

The specific information that was defined for each question-template was then segmented into its five sub-components. They are described below and visualised in the left image in (Fig. 1):

- **Authoring:** This component contains the form to insert the parameters needed for the question during the authoring process.
- **Appearance:** The overall layout of the question is described within this component. It provides the framework of the question and embeds the other components.
- **Evaluation:** This component contains the routines that are needed to evaluate a graphical question.
- **Graphics:** This component contains the vector graphics that built the graphical part of the question as well as the underlying image that is used within some of the templates.
- **Action:** This component includes the routines that catch the events from the learner and handle the reactions within the question. It controls the behaviour of the presentation component.

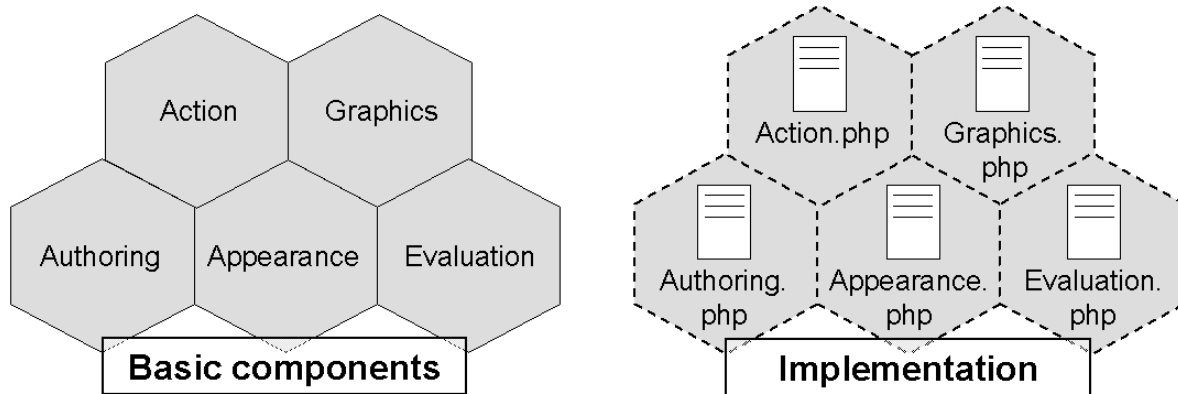


Figure 1: The components within the GIA system

4.2 Implementation

The approach for the implementation of this modular concept that was taken in the GIA-project was to build files that each inherits the tasks of one of these components. One question template thus consists of five files that are based on the basic components that were described above (see right image in Fig. 1). The template-files are implemented in PHP and build the presentation window using HTML for the frame and the 2D-Vector standard SVG (W3C 2003) for the graphical elements. Another used technology is JavaScript (or ECMAScript) for the interaction, which allows building and interactively adjusting the SVG-image by modifying the DOM (Document Object Model). A more detailed explanation of the implementation is given in (Böhm, Dietze 2004)

4.3 Development of New Question Templates

The concept above provides the skeleton for the development of question templates. The question-template-developer is requested to elaborate contents for all five files. It should provide the developer with sufficient freedom to build adequate presentation and authoring environments for a large variety of innovative and highly interactive questions. Since the evaluation of the questions is performed by algorithms, described by the template developer, there is virtually no limitation on this aspect in terms of complexity and extensiveness. When a new question is built based on one of the templates, the actual descriptive data of the concrete question is stored in the database of the core system.

The relations of the skeleton, a question template and a concrete question might be described by the terminology of the object-oriented paradigm:

<i>OO-Terminology</i>	<i>GIA-Term</i>
Abstract Class	Question Template Skeleton
Class derived from the Abstract Class	Question Template
Instance of a Class	Question built out of a Template

Table 1: Terminology used in GIA

4.4 Templates for the Surveying and Geoinformatics Community (SGC)

In section 2.1 we identified the specific requirements for the SGC with regard to graphics based assessments. Based on these requirements a set of question templates was developed. Those templates will be presented within this section with reference to the requirements.

4.4.1 AREA and BUFFER

Both question templates integrate a background image (raster image) and allow the user (the learner) to draw a polyline out of several points that are connected with each other through line segments. This polyline has to be within a buffer area that needs to be defined by the author of the question. It is possible for the learner (as it is the case in all the following templates), to zoom into the image in order to set the points on an exact position. The AREA template is the basic version for this type of question and was developed first. The BUFFER template is an enhanced and more recent version of the AREA template. Its automatic evaluation routines are further developed.

Exemplarily two questions are mentioned here, but certainly there are many other potential questions that can be built out of these templates:

- The question shows an image of a city map. The learner has to draw a traverse between given reference points.
- An aerial picture is shown. The task here is to digitise a linear element or a specific area, e.g. roads or an industrial area (see Fig. 2).

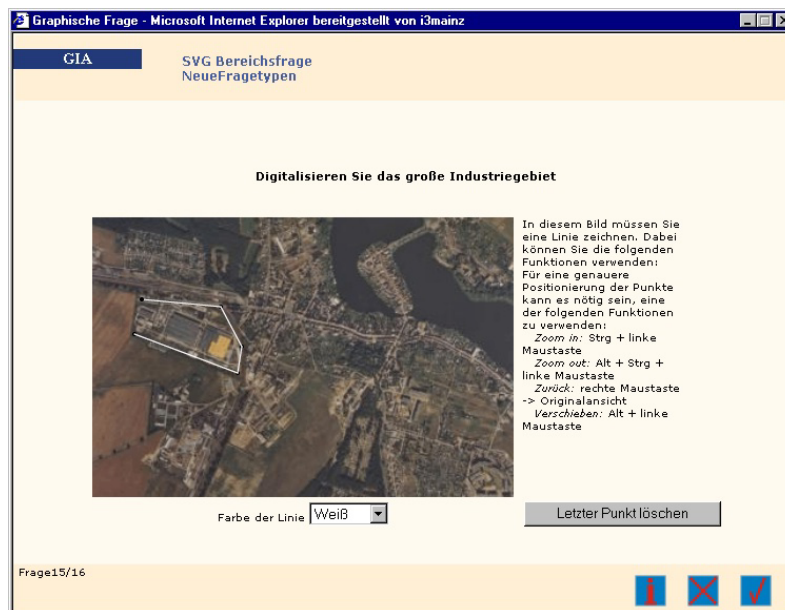


Figure 2: The BUFFER template, drawing on an aerial picture

4.4.2 CODE and EVAL

A question built based on each one of these templates shows source code within a window. The task for the learner in the CODE-template is to mark one row within this code. It is also possible for the author to ask for several rows and then store the sequence of the clicks as the answer. A potential example is to show the source of a java-application. The learner now e.g. has to show that he understands the concept of inheritance and in which order the methods (e.g. toString) of the derived classes are called. This template can be seen in the following figure.

The EVAL-template differs from the first one in that it asks for an arbitrary answer in a text-field. This can e.g. be the result of a calculation obtained from the application routines. As the window for the source code is comparably small to show the whole application logic, it is possible to navigate through it using the arrows on the right side of the screen.

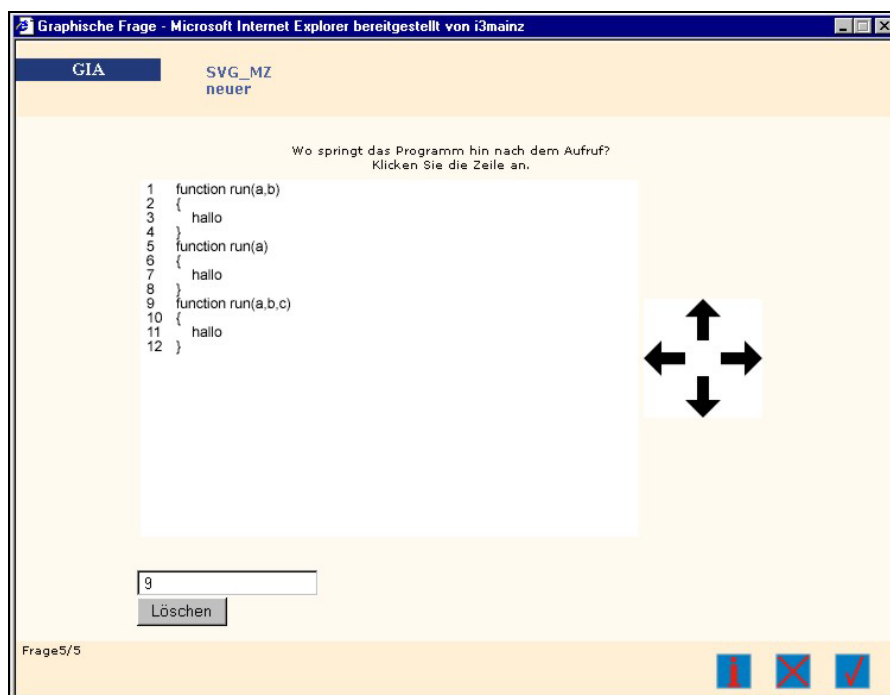


Figure 3: The CODE template: selecting a line within some source code.

4.4.3 IMAGEBW and IMAGEC

Both templates were developed for questions within the field of digital image processing. They show two raster images. The left one is the original and the learner has to draw the modified result in the right image. This can be the result of a median-filter (3x3 pixel), for instance.

The IMAGEBW-template is made to draw black and white images (values 1 or 0), the IMAGEC-template allows values between 0 and 9 (greyscale). The first template is therefore faster to build but the second one allows more complex questions.

The following figure 4 shows a question based on the IMAGEC-template as it is shown in a questionnaire.

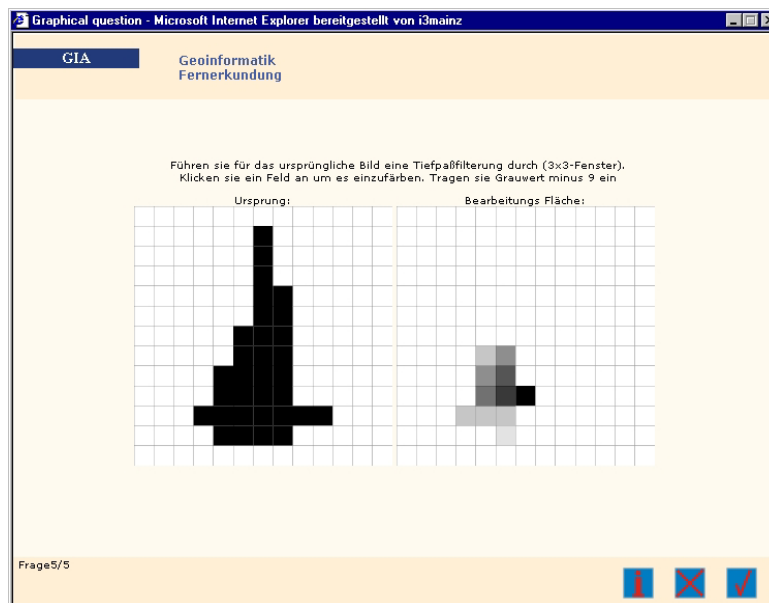


Figure 4: The IMAGEC template, filtering a raster image

4.4.4 MEDI

This template is an extended version of a multiple choice question. An image is shown on the left side of the screen. The author of the question can draw an arrow on this image to point out a specific feature on it. On the right side there are several answers with radio buttons wherefrom the learner has to select the correct one.

The question can be related to something that is marked on the image; this can be e.g. a point on a city map or on an object in an aerial image.



Figure 5: The MEDI template, answering a question about an object in an image

4.4.5 PHOTO

The PHOTO template was developed to ask a question from the subject of photogrammetry. The ground control points needed for the planning of an aerial flight (for photogrammetric measurements) have to be selected. The learner has to know on which positions it is needed to have a height, a location or a full ground control point in order to be able to use the resulting images as a basis for digitalisations. One example can be seen in Figure 6.

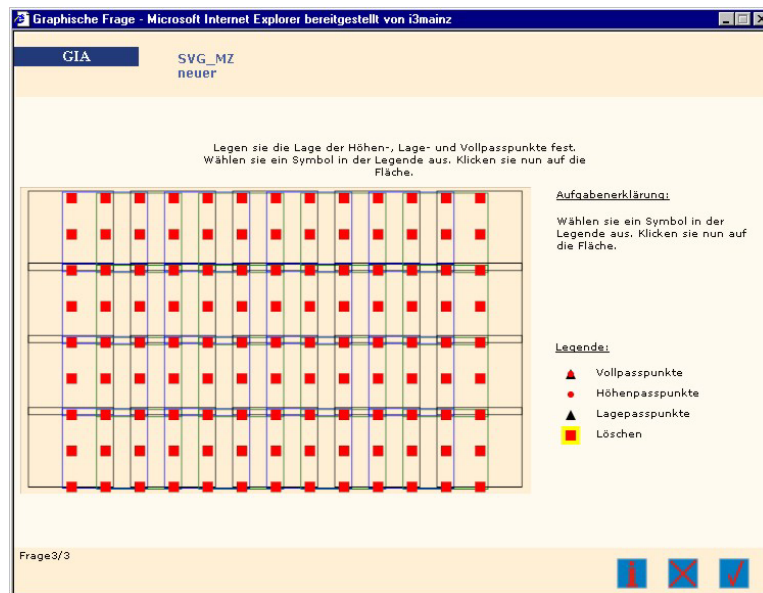


Figure 6: The PHOTO template, planning a photogrammetric fly-through

4.4.6 POINT

A question based on this template also shows a background-image. The task for the learner hereby is to draw one or several points on this image. These points are then automatically compared with the positions given by the author. Examples for the use of this template are e.g. to ask the learner to identify the position of a city on a map (see Figure 7) or to find the marked ground control points on an aerial picture. Especially for the second example it is important to emphasise, that it is possible to zoom in or out of the image to set the points.

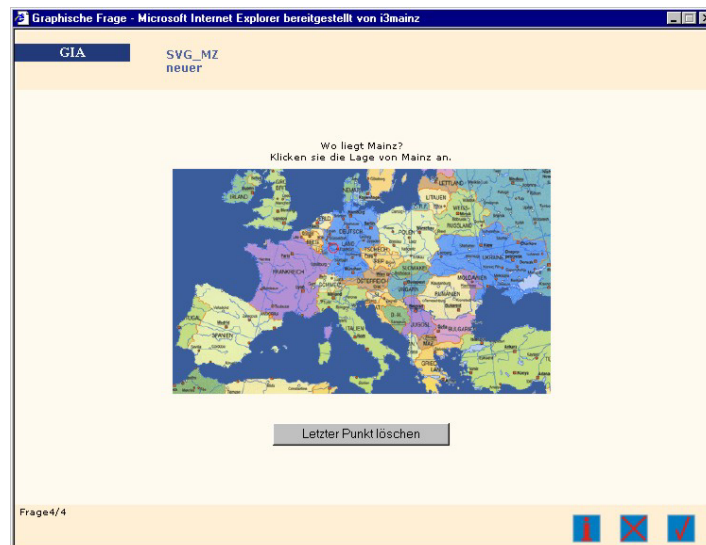


Figure 7: The POINT template, drawing of one or more points on an image.

The process of the authoring is further elaborated in (Böhm, Dietze 2004). Other developed question-templates are described in (Böhm, Dietze 2005).

4.5 Evaluation within GIA

An important part of the templates is their potential for being automatically evaluated. Every template may have its own evaluation routine which will be applied during the evaluation process. After a learner performed a test, the automatic evaluation can take place. At that point in time, the evaluation algorithms described in the “Evaluation”-files are applied. The first step of the evaluation is to get the description of the correct answers defined by the author and the answers given by the learners out of the database. Then they are evaluated using the respective Evaluation-files where several calculations according the specific algorithms are done in order to find out if the question has been answered correctly. The results of this evaluation process are stored in the user’s account and may be checked by him. In contrast to multiple choice test, some graphical questions may leave space for interpretation of the learners answers. This fact, of course, increases with the flexibility within the questions. Therefore the GIA evaluation management allows the author to decide if there should a post manual evaluation be done after the automatic evaluation process. During this optional post manual evaluation the author views the graphical result of the learner together with the own suggested answer. The author may then alter the evaluation result suggested by the automatic process.

4.6 Example of the Evaluation

The complexity of the evaluation routines differs of course with the complexity of the desired kind of questions. In the following chapter an example evaluation approach is presented for the BUFFER-template. This workflow differs for other question-templates during authoring and evaluation.

The BUFFER-question requests the learner to define a polyline by setting a number of points on a given image. The task might be to draw a traverse on a given street-map or a border around a specific area within an aerial picture.

– Authoring:

During the authoring process the authoring-template prompts the author to insert the needed parameters: question-text,-description and the metadata. He further has to upload the file of the background-image. The size of this image is scaled to the window-size of the template. Now all the graphical elements of the image are shown. The author now needs to insert (resp. draw) the correct answers into the image – in the here described example the tolerance buffer around a polygon. This buffer is stored in the database as the “correct answer” to the question.

– Answering the question by the learner

The polyline drawn on this image by the learner is stored as the “given answer” in the learners profile within the database.

– Evaluation

The evaluation-template receives the correct and the given answers within two arrays. They are compared as described below and shown in (Fig. 8). The result of the comparison can then be viewed together.

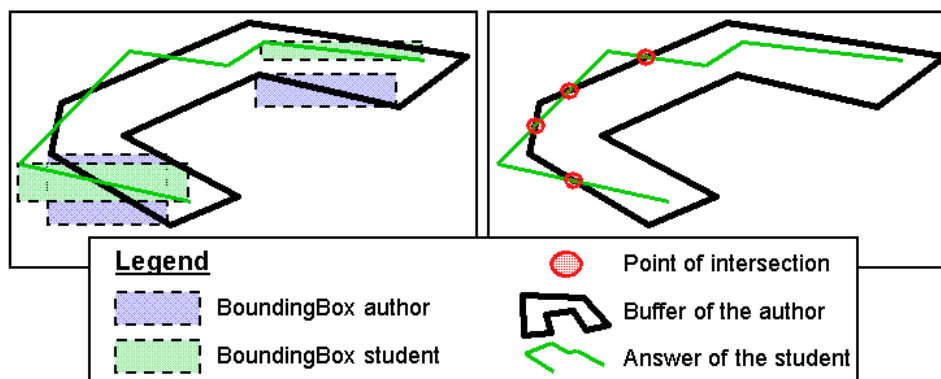


Figure 8: Evaluation within the Buffer-template: comparison of the BoundingBoxes and the line sections, if necessary.

The evaluation algorithm first compares the Minimum-BoundingBoxes of each segment of the polygons. If they overlap, then a second comparison process takes place. Thereby the segments itself are compared for intersections and the total amount of intersections is counted. Afterwards the position of the first point is determined. With this information it is now possible to use the number of points (even or odd), to find out which points are within, and which ones are outside of the buffer.

```
foreach segment buf in the buffer
    foreach segment poly in the given polygon
        bool = isIntersectionBoundingBox(buf, poly)
        if (bool)
            checkIntersectionSegment(buf, poly)
            nNumberOfIntersections++
```

Furthermore the length of the given answer is compared with the buffer. The sum of these criterions is used for calculating the numeric result of the answer. Thresholds per criterion define the requested minimum of correctness. The result of the automatic evaluation is shown to the author during the optional post manual evaluation process.

5. CURRENT RESULTS

The GIA core system is running as a stable prototype. This prototype is currently applied in the targeted application environment of SGC at the University of Applied Sciences in Mainz.

5.1 Requirements and the Corresponding Templates

Not all the requirements could be fully fulfilled with the templates developed, some templates are very sophisticated but others currently have a reduced scope. The current status of completion and the corresponding templates can be seen in the following table 2. This table shows which templates have been developed and to which topics they correspond. Up until now no template has been finished that provides simple GIS functionality. But especially the BUFFER-template has been extensively tested and improved and meets the needed requirements.

<i>Requirements</i>	<i>Templates</i>
Graphical identification of areas	AREA, BUFFER, POINT
Determination of trajectories	AREA, BUFFER
Processing of raster graphics	IMAGEBW, IMAGEC
Source Code workflow	CODE, EVAL
Planning of aerial flights	PHOTO
Identification of objects	POINT
GIS functionality	---

Table 2: Requirements from the SGC and the corresponding templates

5.2 User Tests

The first user tests were carried out in November 2003 and January 2004. Altogether 52 students from different semesters (with different levels of experience) of studying geoinformatics at the University of Applied Sciences conducted the test. Although the number is not completely representative it provided important results and feedback, both to the concept and the system functionality. The students were very open-minded towards this new way of accomplishing tests. More than 80% of them liked these types of questions better than multiple-choice questions. A similar percentage of the students can also imagine to have such tests as assessment within the scope of lectures.

Beside these tests the GIA framework is also used for evaluation of the lectures within the continuing education program at the University of Applied Sciences in Mainz. This can be seen in (Fig. 7). The students of the Geoinformatics studies evaluate the professors and their

lectures using pre-defined questionnaires. As these questions are used each year, a continuous monitoring of the development of the quality is possible.



Figure 7: Evaluation of the lectures using the GIA framework

The use of the authoring framework was also evaluated by several authors: professors and scientific assistants at the University of Applied Sciences in Mainz. The whole system was assessed as good and no major improvements were requested to the general concept of the graphical questions. Especially the evaluation of the lectures was interesting for these authors to be used within the scope of their lectures. This positive feedback shows that the interest of the students within this area was perceived by the professors.

6. FUTURE WORK

With respect to the potential of automatic generated and evaluated graphical questions, the result of the project can be seen as the starting point for further investigations in various directions. Most important is the development and test of not only the existing but also additional question templates. Here the development of appropriate evaluation criteria and routines might be most crucial. In addition to the use 2D graphics for questions, the inclusion of time dependent data, audio and video seem logical for the future development. Moreover integration of three dimensional scenes for questions should be considered.

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BIOGRAPHICAL NOTES

Klaus Böhm and **Hartmut Müller** both have been working as academic teachers at sub-department Geoinformatics and Surveying of Mainz University of Applied Sciences for several years. Klaus Böhm received his diploma and doctoral degree at the Technical University in Darmstadt in computer science with specification in Computer Graphics. Currently he is a visiting professor at the University of Nebraska at Omaha. Hartmut Müller gained his diploma and doctoral degree in Geodesy. Leonhard Dietze holds a diploma degree in Geoinformatics and Surveying. He currently works as scientific co-worker at the i3mainz institute.

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