Masters Program in Geospatial Technologies

TESTING NATIVE SPEAKERS OF GERMAN AND PORTUGUESE ON THE UNDERSTANDING OF TOPOLOGICAL OPERATORS – LINE-REGION RELATIONS IN gvSIG

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ABSTRACT

Usability testing is an essential part of software development, which provides guidelines to the developers according to the users' needs. In the present usability study, natural language terms that describe topological operators in gvSIG software were tested among native speakers of German and Portuguese. The main goal was find out if users' understand the operators according to the system designer.

Twenty six subjects in each language had to choose the line-regions relations appropriate for each topological operator in gvSIG. Afterwards, the subjects' answers were compared to the implementation of these topological operators by the gvSIG software. The comparison revealed major difference between the subjects' answers and the gvSIG implementation. The subjects chose applicable line-region relations out of a set of 19 different topological relations identified by Egenhofer's 9-intersection model.

In average 12% and 6% of the operators were understood in the same way as gvSIG implementation by the subjects of German and Portuguese respectively. For German native speakers, the highest results of an operator understood by the subjects as the system designer were 50% and a subject understanding 33% of the operators. The lowest results of an operator understood by the subjects as the system designer were 0% and a subject understanding 0% of the operators. For Portuguese native speakers, the highest results of an operator understood by the subjects as the system designer were 27% and a subject understanding 33% of the operators. The lowest results of operator

understood by subjects as system designer were 0% and a subject understanding 0% of the operators.

KEY WORDS

Line-region relations

Topological operator

Usability testing

ACRONYMS

GIS(s) - Geographic Information System (s)

gvSIG- Generalitat Valenciana, Sistema d'Informació Geogràfica (Open source GIS software developed by Valencia government, Spain)

ISEGI- Instituto Superior de Estatística e Gestão de Informação (Higher Institute of Statistics and Information Management)

OGC- Open Geospatial Consortium

PDF- Portable Document Format

XML-Extensible Markup Language

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1. INTRODUCTION

Computer user interfaces have recently gained more recognition than they used to be. Myers and Rosson (1992) pointed out that 48% of the code are dedicated to the user interface in the software development in recent years. Furthermore, the revolution in personal computers and falling of hardware prices are making computers available to ever broader groups of users, and in this case computers are made to perform a larger variety of tasks (Nielsen 1992). On the other hand, software interfaces still do not employ all the languages spoken in the world. They implement few major languages or quite often English.

GIS users often find themselves in a situation where they would like to perform spatial queries in a scenario that resembles a region and a line in the real world. For instance, scenarios such as river flowing into a lake, a railway crossing a country or a university campus near a highway could all be represented in GIS using line and a region. In this situation the river, railway and highway are represented as a line and lake, country and university campus as a region. GIS software use natural language to describe topological operators in spatial queries. The terms "*share a line segment with*", *"crossed by", "contained in", "touch the boundary of"* etc could be interpreted differently from what a system designer intended. Riedemann (2005b) suggested various reasons that could be the causative of the problem. First is the early availability of new versions or those that comes only in one language, say English only (in non-native English speaking environment). Secondly, the term might not be appropriate for the operator they are describing. Thirdly, the graphics depicting the operator might be misleading or even the combination of the graphics and natural language terms pose misleading effect. Another reason is that the operator may not be according to human concepts and tasks. Riedemann (2005b) pointed out the needs for these problems to be studied separately and in combination.

Some GIS software such as gvSIG comes with a multilingual user interface, which theoretically would eliminate the problem of non-native speakers for the languages that are included in the software. Yet the question still prevails if users from one language have an advantage of understanding the terminology better than others.

This study is restricted to the native speakers of two languages (German and Portuguese) and line-region relations. The line-region relations of the 9-intersection model by Egenhofer and Herring (1990a) are the ones used in the study. The natural language terms that describe topological operators in GIS can map to none, one or several of these topological relations. The natural language terms and the arrangement of mapping vary across different GIS products. This has been clearly shown in the (Riedemann 2005a; Riedemann 2005b) studies. For the case of this study gvSIG is used and testing is done on the natural language terms (operators) in the new employed topology extension (alpha version).

1.1 Study Motivation

The conception of this study was motivated by the previous work on the *Naming of the Topological Operators at GIS User Interfaces* (Riedemann 2005b). The study seeks to expand Riedemann's work with respect to two aspects. It increased the number of languages to be tested where by the native speakers of German and Portuguese were taken as study subjects. The line-region topological relations were used instead of region-region relations that were used by Riedemann (2005b). Considering the growing interest in usability testing and gvSIG as one of the open sources software with a multilingual user interface and currently undergone development was taken as one of the choice to see the usability level in its newly employed topology extension (alpha version). The study aims at providing the developers with the relevant information to make the necessary changes to better suite users' needs.

1.2 Objectives

Main objective of this study was to test human subjects of German and Portuguese native speakers on the understanding of topological operators on the GIS user interface (gvSIG) for the line-region topological relations and compare the results with the operator's implementation in the gvSIG software. The understandings results can also be compared among the two languages subjects.

To achieve the main goal, various aspects were taken into consideration. These include:

(i) Run topology test of the line and region shape files in the gvSIG to find the line-region relations that are applicable for each topological operators of the gvSIG software.

(ii) Translations of the existing gvSIG operators from Spanish to English and later to German and Portuguese

(iii) Human subjects testing on the understanding of topological operators as implemented by gvSIG system designer.

1.3 Research Problem

Spatial databases and GIS products use queries to perform various tasks. In GIS products natural language is used to describe topological operators in spatial queries. The natural language terms have shown little serving in the purpose of the system designer (Riedemann 2005b). While there are several types of topological relations only region-region relations have been tested on the real GIS software. Riedemann (2005b) suggested testing other topological relations as they are equally important. In this case, the line-region relations will be examined in this study. Just as there are different words describing similar things, it was found that some words have better scores when used as topological operators compared to the ones used in the GIS products (Riedemann 2005a). It is now known that the choices of the wording to be used as spatial operator are very important. The misunderstanding of the operators lead to the testing of the natural language terms used to describe topological operators in gvSIG on its developed topological extension against its users. Native speakers of Portuguese and German are the candidates for the test as the product support multilingual user interface. Usability testing is important especially for the new software or when an extension is about to be added to the software.

2. LITERATURE REVIEW

2.1 Descriptions of a line and a region

The description of a line and a region is given because of its importance in this study. A region is a two dimensional object as it occupies an area (Longley, Goodchild et al. 2005). Regions can also be branched into those with or without holes. A region without holes is a region with a connected boundary such that it has both connected interior and exterior (Figure 1(a)). A region with holes is a region with a disconnected boundary such that it has both disconnected interior and exterior (Figure 1(b)). A line is a one-dimensional object such that its points form a sequence of connections and never cross each other or form a closed loop. Line can be complex or simple. A simple line is a line with two disconnected boundaries; the boundaries of the line are its two end points (Figure 1(c)). A complex line is the one with more than two disconnected boundaries (Figure 1(d)) (Egenhofer and Herring 1990a). In this study, a region without a hole and a simple line are the one considered because are the ones commonly used in GISs (Clementini, Felice et al. 1993).

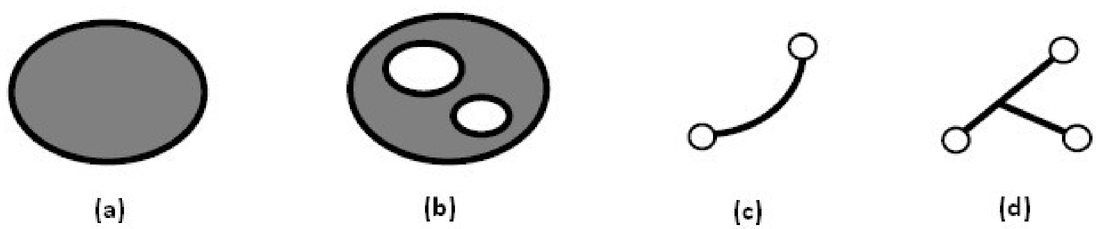


Figure 1: (a) Region with connected boundary (b) Region with disconnected boundary (c) simple line (d) complex line. Images adopted from (Egenhofer and Herring 1990a).

2.2 The possible line-region topological relations from the 9-Intersection model

It is possible to have an infinite number of topological relations but the formalization of the theories of the topological relations resulted into finite number of these relations (Riedemann 2005b). The major theories are the 9-intersection model by Egenhofer and Herring (1990a) and the Dimensionally Extended 9-Intersection model or Clementini matrix (Clementini, Felice et al. 1993). The 9-intersection model will be discussed here because it is widely used in the GIS applications (Riedemann 2005a; Riedemann 2005b).

The 9-Intersection model is the comprehensive binary topological relations *R* that is applicable to area, line and point (Egenhofer and Herring 1991). It characterizes the topological relations between two-point sets say A and B. Each point set makes three object parts in which point set A gets interior (A^o), boundary (∂A), exterior (A-) and point set B gets interior (B^o), boundary (∂B), exterior (B-). The combination of the six body parts forms the 9-intersection as summarized in the 3X3 matrix equation (Equation 1) (Egenhofer and Herring 1990a).

$$R(A,B) = \begin{pmatrix} A^o \cap B^o & A^o \cap \partial B & A^o \cap B^- \\ \partial A \cap B^o & \partial A \cap \partial B & \partial A \cap B^- \\ A^- \cap B^o & A^- \cap \partial B & A^- \cap B^- \end{pmatrix}$$

Equation 1: The 3X3 matrix equation that form the 9-intersection. The equation was adapted from (Egenhofer and Herring 1990a)

There are several topological invariants that are applicable to 9-intersection. The content (emptiness or none-emptiness) is simple and the most general topological invariant among all (Egenhofer and Franzosa 1991). The 9-intersection can be used to analyze if different configurations resemble in topological relations. This is simply possible due to the fact that some sets of intersection are physically not possible (Egenhofer and Herring 1990a). The concept of topological equivalence is introduced in Egenhofer and Herring (1990b) which encompasses those relations with the same specifications.

Based on the distinction of the content (emptiness or non-emptiness), the intersection model sums up a total of 512 (2^9) possible relations between two sets but only smaller number of them can be realized in a particular space (Egenhofer and Herring 1990a). Furthermore, more distinctions can be realized when other factors such as dimensions of intersection and number of separate components per intersection are treated together with non-empty intersections (Egenhofer and Herring 1990a; Clementini, Felice et al. 1993).

This study confines itself to the topological relations between a line and a region. There exist 19 topological relations (Figure 2) with the 9-Intersection model between a simple line and a region embedded in R^2. The numbers 0's and 1's in the matrix in each of the picture diagrams in the figure represent empty and non-empty respectively (Egenhofer and Herring 1990a).

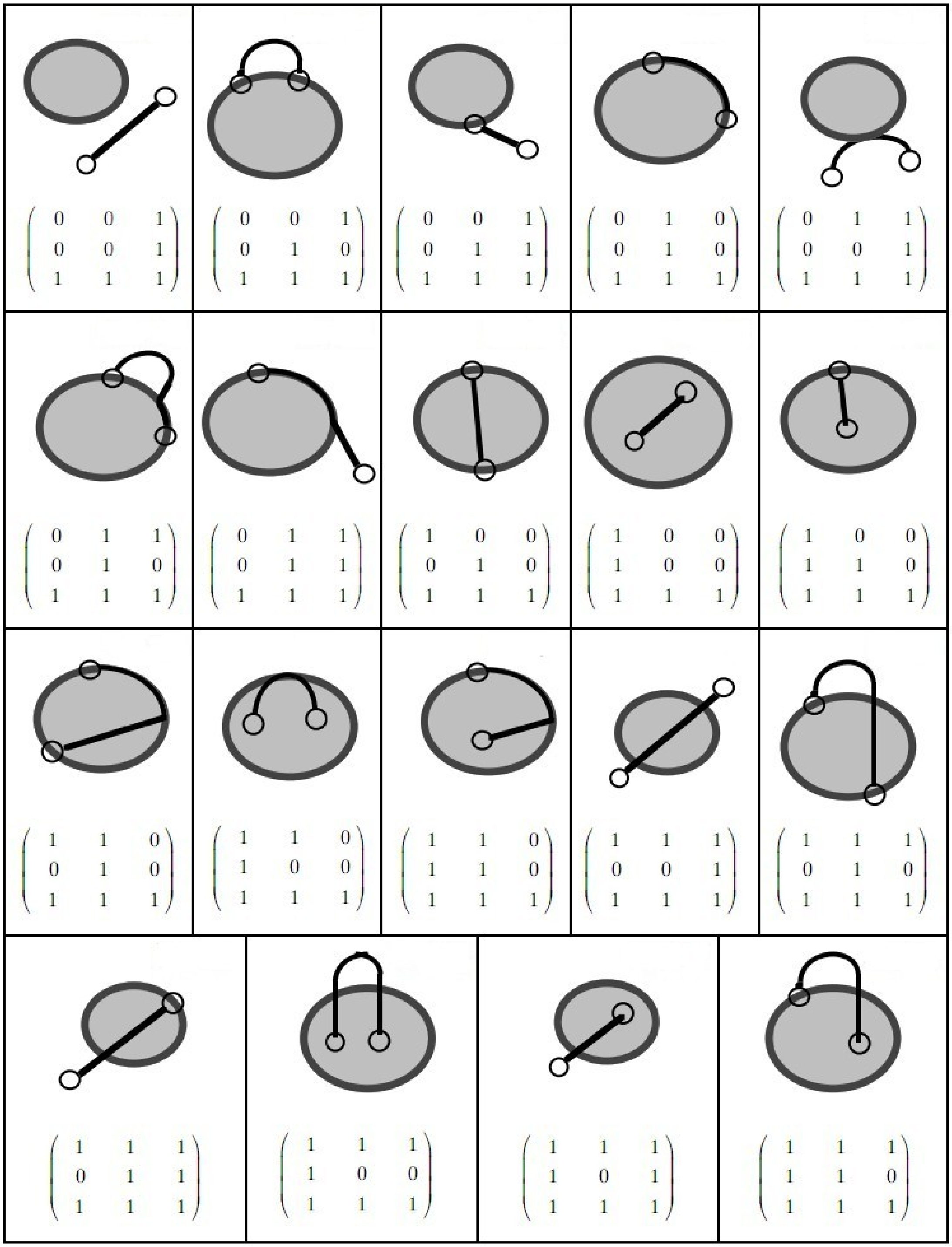


Figure 2: Geometric interpretation of the 19 line-region that can be distinguished from the 9-intersection model (Egenhofer and Herring 1991)

2.3 Related work from a non-GIS software testing

The human factor has been missing in most of GIS literatures (Mark and Egenhofer 1994). In the past, research on the fundamental theories of spatial relations was dealt with different independent motivations. The GIS software designers were part of the independent motive in which they developed solution for implementation of spatial relations and also concepts that are required for the real working GISs. The approach used in developing software often produced ad hoc results that are impossible to generalize from or extend. The approach is based on mathematics to produce sound definitions as the basis for query algebra, but it was still in doubt the correspondence of mathematical model to human thinking (Mark and Egenhofer 1994). Mark and Egenhofer (1994) found that it is necessary for inclusion of the human spatial cognition in the research that is leading to fundamental theories of spatial relations and therefore set a study.

In their study Mark and Egenhofer (1994) conducted an experiment to test how people think about spatial relations between lines and region. The region is treated as a national park while a line as a road. Two experiments were conducted in their study. One was for the human subjects to group various drawings (road and national park) and later gave descriptions to created groups. The human subjects were native speakers of English, Chinese, German and Hindi (used English). Although there was great deal variation in the way human subject classifies a spatial situation that involves road (line) and parks (region) the results suggested many of the qualitative difference made by people regarding spatial relations are captured by the 9-intersection model (Mark and Egenhofer 1994). They found a great deal of language based-difference. They called for more experiments with larger sample and/or more focused experiment including testing speakers of other languages on cultural or linguistic differences.

The second experiment of Mark and Egenhofer was for the human subject to rank on the agreement of the spatial relation between a “road” and a “park”. This was according to the two given sentences “the road crosses the park” and “the road goes into the park” for testing. The two spatial predicates were drawn from the subjects’ responses in the first experiment. The results were mixed for the two sentences tested. It was found that some situations were strongly confirmed as belonging to both “the road crosses the park” and “the road goes into the park”. Other situations belong to one concept and not the other but some fit neither of the descriptions. It was concluded from the results that no single set of mutually-exclusive and collectively-exhaustive spatial predicates could satisfy all the queries or natural language descriptions.

In the overall recommendations, the authors suggest testing with other languages, increasing the larger sample and for the second experiment it was also suggested that it would be more clearly applicable to GIS if the queries were from GIS context (Mark and Egenhofer 1994). Relating Mark and Egenhofer (1994) studies to this thesis, the natural language terms (operators) used in the gvSIG topology extension (real GIS software) were tested against the native speakers of German and Portuguese. And the same line-region relations were used. The numbers of people tested in each language are also higher for the two languages involved. All these studies are useful in providing guidance to the mathematician and software engineering as to which distinctions are worth making and which are not.

In another study, English and Spanish subjects were given the task of drawing. They were given a blank outline of the polygon shape that signifies park and asked to draw a line (road) according to the sentence given (Mark and Egenhofer 1995). Shariff, Egenhofer et al (1998) came with another approach by analyzing the geometry of drawings using English language subjects where by the metrics was introduced to refine the nine intersection model.

2.4 Related work from Riedemann (human subject testing from GIS software)

Testing of the natural language terms that describe topological operators and their implementations according to the system designer of the GIS products has never been done before. This has come at the right time as usability testing is increasingly become important to the user interface.

The first study to examine the topological operators used in the real GIS products was done by Riedemann (2005b). The human subjects were tested on the understanding of natural language terms that are used to name topological operators in a GIS products as intended by software designer (Riedemann 2005b). Riedemann used region-to-region relations to test the implementations of the two GIS software, ArcGIS[1] and GeoMedia[2] and found that the majority of studies human subjects didn't understand the topological operators in the same way as the mentioned systems. The overall results showed that the average recognition rate of ArcGIS operator was 19% while that of GeoMedia was 36% respectively. Neither of the tested GIS products showed average recognition rate of above 50%. These findings are raising challenges to other GIS software developers as ArcGIS and GeoMedia are not the only existing GIS products.

It is also important to carry out usability testing throughout the lifecycle of the product with much done at the beginning before the release of the product or product extension(Gould and Lewis 1985). In this study, the usability testing of gvSIG is done before the translations of the topological operators to other languages. Portuguese and German languages are used in the testing and the timing is great since gvSIG topology extension is still in alpha stage. Riedemann (2005b) argued that good operator name should be scored by more than 50% of

[1] ArcGIS is a GIS software of Environmental System Research Institute (ESRI)
[2] GeoMedia another GIS software of Intergraph Corporation

users or even higher expectations. The author used only native German speakers. This brings up another question, whether people from other languages can have different understandings or not. Howard (1989 p77) argued that "*despite the many ways in which culture and language influence each other, their integration is not absolute. Each has many properties uniquely its own that are not directly, or even indirectly, influenced by the other*".

2.5 The choice of Spatial Operators in GIS

In the GIS arena, whether spatial database or GIS applications, spatial queries are used to perform different tasks. However, the natural languages terms fitting to the spatial operator used in GIS applications differ and so do their implementation in the system designer. In the research done by Riedemann (2005b), the ArcGIS use the following terms; *are crossed by the outline of , intersect, are completely within, share the line segment with, touch the boundary of, are identical to, contain, are contained by.* On the contrary, the GeoMedia use *touch, contain, are contained by, entirely contained by, overlap, meet, are spatially equal.* This shows a great variation on the natural language terms used by different software. The gvSIG has different natural language terms as well. It is found that some terms are preferred more by the users compared to the others.

Riedemann (2005a) did also test the natural language terms other than those used in GIS products. The results showed that human subjects chose the operator terms that were not used in GIS products, which necessitated the rewording of the user interface of the GIS products. Riedemann(2005a) was not aware why the operator terms that were not in GIS products were chosen by the subjects. This is when the usability testing is supposed to go hand in hand with the product life cycle to identify those preferred by humans. Riedemann (2005a) used region-region relations and pointed out that humans do have concepts of lines and points.

The Dimensionally Extended 9-Intersection Model of Clementini, Felice et al (1993) provides eight operators betweens points, lines and polygons which are used to test the spatial relationship between two geometry objects. The operators are *equals, disjoint, intersects, touches, crosses, overlaps, within and contain*. These operators have been included in the International Standard for Simple Feature Access (ISO 2000).

3. METHODOLOGY

Participants, who are native speakers of German and Portuguese, were tested on how they understand the operator implementation of the line-region as used in the gvSIG software. The gvSIG software was learned in the class during author's first semester in Spain. During the time period of this thesis research, gvSIG documentation did not explain which line-region relations are implemented by which operators. Rather, the user was required to use two different shape files: in this case, a line and a region. Nineteen different shape files of a line and region relations were created from the Egenhofer 9-intersection model. These were tested on the gvSIG topology extension to create the rules to use in the testing of the German and Portuguese respondents. The gvSIG topology extension was employed for the first time (alpha) and the new version of gvSIG 1.9 RC1[3] were used to identify the operator implementations for the line-regions. Figure 3 show some of the created shape files of line-region relations, which were used to create rules to determine whether the respondents' understanding is in line with what was intended by the software developer.

[3] Final stage in the software development (RC-Release Candidate)

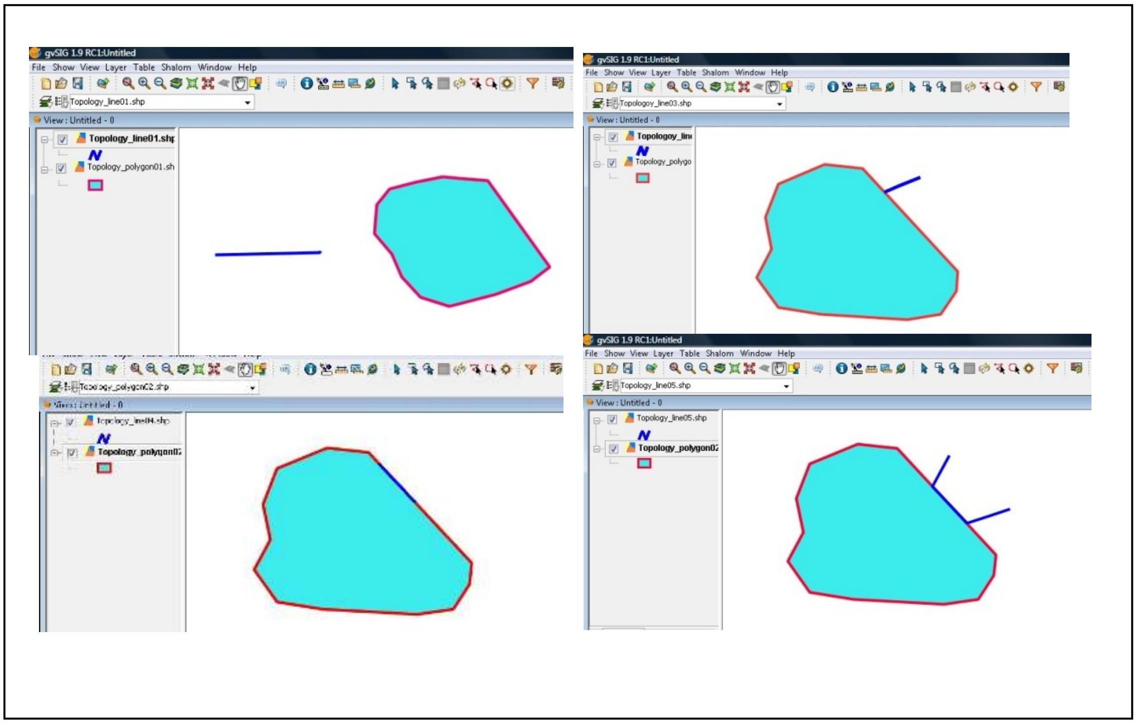
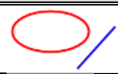
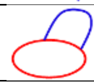


Figure 3: Some of the region and line shape files created for testing topology extension in gvSIG

The applicable topological relations (line-region) that satisfy different topological operators are shown in Table 1. The X in the table means that the topology relation on the left side of the table (along the row) is applicable for that specified operator (along the column). The blank means that the topological relation on the left side of the table (along the row) is not applicable under the specified operator (along the column). The operators have been adapted from the gvSIG software but are original in Spanish and for convenience they are presented in English, translation can be seen in Table 2. The letters A and B in the operators means that two different shape files. The blue line represents a line and a red circle represents a region. Position numbers (1-19) of each topological relation on the first column identify each topological relation and will be used in the result tables (appendix 2 and appendix 3) and throughout the discussions in this thesis when a number is referred to a line-region relation.

Operators / Line-region Relations		The geometries of A must be contained by the geometries of B.	The geometries of A must be covered by the geometries of B.	Each geometry in A must have an equivalent geometry in B.	Each geometry of A must contain a geometry of B.	Each geometry of A must cover a geometry of B.	Each geometry of A must intersect a geometry of B.	The geometries of A and B must be disjoint.	Each geometry of A must touch one geometry of B.	Each geometry of A must be covered by one or more geometries of B.
1								X		
2							X			
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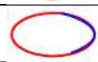
4							X			
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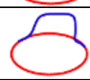
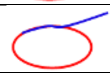
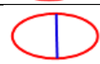
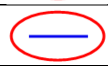
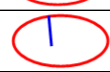
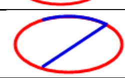
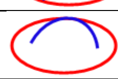
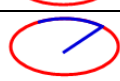
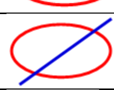
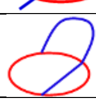
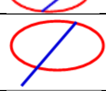
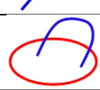
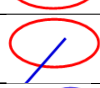
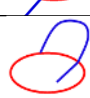
6							X			
7							X			
8							X			
9		X	X							X
10							X			
11							X			
12							X			
13							X			
14							X			
15							X			
16							X			
17							X			
18							X			
19							X			

Table 1: gvSIG operator implementations for the line-region relations

The questionnaires were designed using Adobe designer 7.0 software and the obtained interactive questionnaire in pdf. The respondents could either completed questionnaire digitally on the computer screen and send it back as an email attachment in a pdf or xml format. Adobe acrobat provides the functionality to read out the data in xml format. Alternatively some respondents printed the questionnaire and completed it on hard copy and returned the hard copy paper. The graphical figures in the questionnaire were arranged in a random order for each page. Randomization of the graphical figures prevented the respondent from assuming that the figures are arranged in the same way, so they should not simply complete sections of the questionnaire based on the pattern experienced on the first pages. Spatial operators were also randomized such that each respondent received a questionnaire with different ordering of spatial operators so as to avoid effects caused by sequential ordering. The randomization was done using one of the randomizer website http://www.random.org/. The effect of randomization can be seen on the two pages presented on Figure 4. The questionnaire itself is in the appendix 4. The questionnaires were produced in German and Portuguese languages, but in this thesis are presented in English for readability. The instructions are in the first page and additional instructions were sent in the email when the questionnaire was emailed to the respondent.

Figure 4: Example of two separate pages of the questionnaire showing effect of randomization

The topological operators in gvSIG software were translated into German and Portuguese. Only Spanish topological operators existed at the time of this usability study because gvSIG[4] previously had no topology extension. The Spanish topological operators were translated into English first, with assistance from a person who speaks both English (native language) and Spanish, and were later translated to German and Portuguese for testing human subjects. English was used as a base for translation to German and Portuguese. The translations to German and Portuguese were done with help of Supervisors, who speak both (German and English or Portuguese and English) languages.

[4] gvSIG is available in different languages including German and Portuguese

The translators are native of German and Portuguese speakers. A total of 9 topological operators were tested against the Egenhofer 19 graphical diagram of line-region relations. The line-region relations were re-drawn and colored for better distinction. Blue and red colors were applied to line and region respectively. The colors were also associated with letters A and B that are in the topological operators. The letters A and B contained in the spatial operators were colored blue and red respectively for easy matching with line and region graphical figures. The respondents were told to mark on whether an operator is “applicable” or “not applicable” to each of the 19 line-regions relations. The topological operators (Spanish) and their translations to English, Portuguese and German are shown in the Table 2.

	Español	English	Portuguese	Deutsch
1	Las geometrías de A debe estar contenidas en geometrías de B	The geometries of A must be contained by the geometries of B	As geometrias de A estão contidas nas geometrias de B	Die Geometrien von A müssen in den Geometrien von B enthalten sein
2	Las geometrías de A debe estar cubiertas por geometrías de B	The geometries of A must be covered by the geometries of B	As geometrias de A estão cobertas pelas geometrias de B	Die Geometrien von A müssen von den Geometrien von B überlappt werden.
3	Toda geometría de A debe tener una geometría igual en B	Each geometry in A must have an equivalent geometry in B.	Para cada geometria de A existe uma geometria equivalente em B	Jede Geometrie von A muss eine äquivalente Geometrie in B haben
4	Toda geometría de A debe contener una geometría de B	Each geometry of A must contain a geometry of B.	Cada geometria de A contém uma geometria de B	Jede Geometrie von A muss eine Geometrie von B enthalten
5	Toda geometría de A debe cubrir una geometría de B	Each geometry of A must cover a geometry of B	Cada geometria de A cobre uma geometria de B	Jede Geometrie von A muss eine Geometrie von B überlappen
6	Toda geometría de A debe cruzarse con una geometría de B	Each geometry of A must intersect a geometry of B.	Cada geometria de A interescta uma geometria de B	Jede Geometrie von A muss eine Geometrie von B überschneiden
7	Las geometrías de A y de B deben ser disjuntas	The geometries of A and B must be disjoint.	As geometrias de A e B são disjuntas	Die Geometrien von A und B müssen disjunkt sein.
8	Toda geometría de A debe tocar una geometría de B	Each geometry of A must touch one geometry of B.	Cada geometria de A toca uma geometria de B	Jede Geometrie von A muss eine Geometrie von B berühren.
9	Toda geometría de A debe ser cubierta por una o varias geometrías de B	Each geometry of A must be covered by one or more geometries of B.	Todas as geometrias de A são cobertas por uma ou mais geometrias de B	Alle Geometrien von A müssen von einer oder mehrerer Geometrien von B überlappt werden.

Table 2: Translations of the gvSIG Spanish operators in English, Portuguese and German

An equal number of 26 human subjects were tested within each of the two native speaker language groups of German and Portuguese. Nielsen (1992 p.224) indicated that for using questionnaires as one of the usability testing methods, 30 is the recommended minimum number of users to be tested. More than 30 respondents from each language were contacted and asked to participate in the study. The German participants were among the workers and students of Institute for Geo-informatics and friends. The Portuguese participants were among the distance-learning students from ISEGI[5] and friends. The participants were contacted by email with the attached questionnaire.

The response rate for each language group was about 87% (26 out of the 30 contacted participants). No incentive was offered and therefore, the study subjects comprised of those respondents who volunteered to participate in a survey. The intention was to obtain the minimum recommended sample size. The participants' composition of each language group is shown in Table 3.

Language group	Male	Female	Average age (years)
German	22	4	26
Portuguese	21	5	33

Table 3: German and Portuguese respondents' composition

Gender and age are considered constant in this thesis as respondents were obtained through email contacts and had to volunteer to fill in the questionnaires which was done through a restricted time frame. However the correlations for age and subjects' answers that are in the same as gvSIG operators' implementations were calculated for both language groups using R[6] and showed a weak positive correlation (Table 4). From the correlation results conclusion can be made that no correlation between age and the subjects' answers. The scatter

[5] Higher institute for of Statistics and Information Management
[6] R is a language environment for statistical computing and graphics

plots of the correlations between the two languages groups (German and Portuguese) were produced to show scattering of the points. The points are away from the line which indicates no correlation between age and subjects' answers (Figure 5 and Figure 6). The y-axis represents ages of the subjects and the x-axis (answers) represents the answers of the subjects that are the same as gvSIG operators' implementations.

Language group	Correlation value
German	0.2717848
Portuguese	0.2208085

Table 4: Correlation between age and subjects' answers for German and Portuguese native speakers

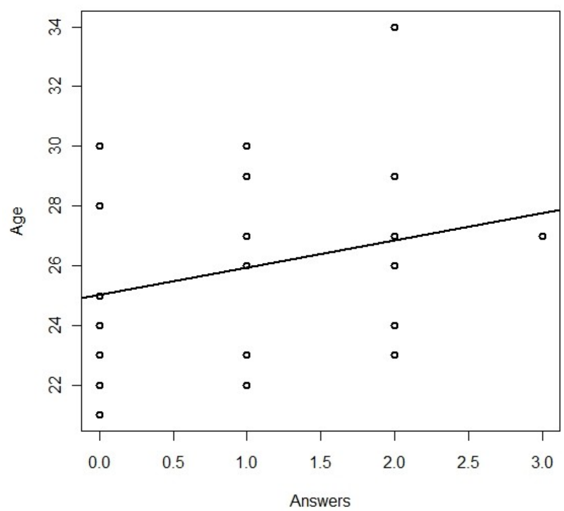


Figure 5: Scatter plot for age against answers for German subjects

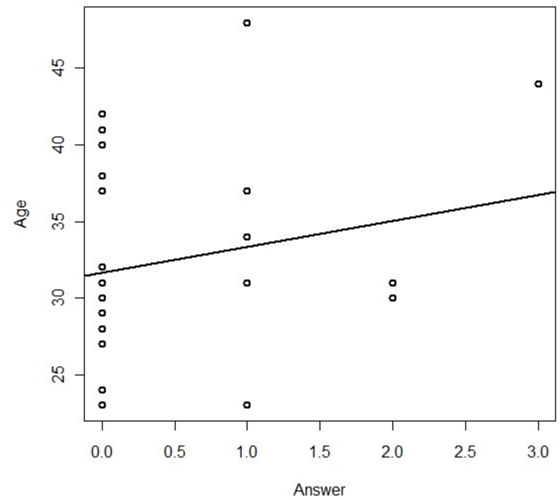


Figure 6: Scatter plot for age against answers for Portuguese subjects

Respondents came from GIS and non-GIS background. The subjects without GIS background were less in number (Table 5).

Language group	GIS experience	Non-GIS experience
German	23	3
Portuguese	22	4

Table 5: Composition of GIS experience for German and Portuguese subjects

The correlation between GIS experience and response was also computed and for Portuguese language group it was found a weak positive correlation between the GIS experience and the subjects' answers that are the same as gvSIG operators' implementations. For the German subjects the correlation is more or less negligible. Table 6 shows the correlation between GIS experience and subject's answers for both language groups. From the correlation results the conclusion can be made that the GIS experience has no effect on the subject's answers that are in line with gvSIG operators' implementations. The scatter plot was also produced to show the distribution of point. The points are way from the line indicating no correlation (Figure 7 and Figure 8). The y-axis (GIS exp) represents GIS experience and x-axis (Answers) represents subjects' answers that are the same as gvSIG operators' implementations

Language group	Correlation value
German	0.01478119
Portuguese	0.2724746

Table 6: Correlation between GIS experience and subjects' answers for German and Portuguese language groups

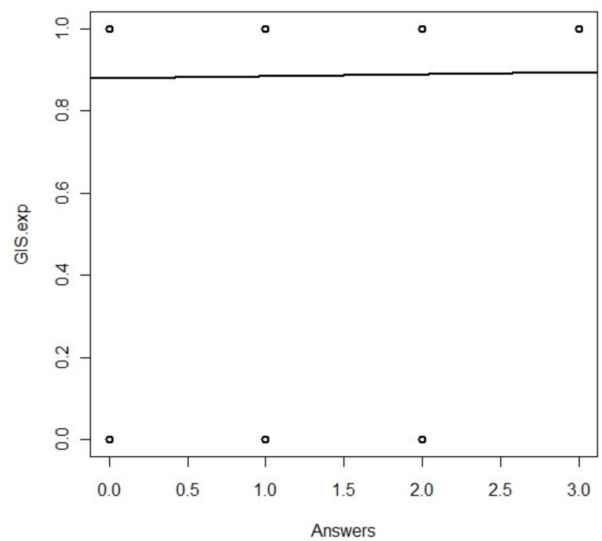


Figure 7: Scatter plot for GIS experience against answers for German subjects

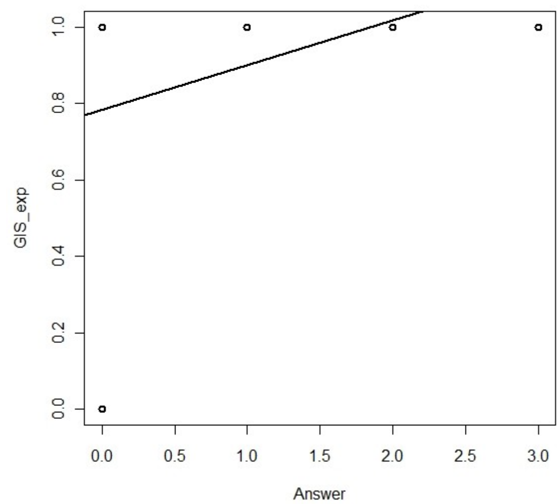


Figure 8: Scatter plot for GIS experience against answers for Portuguese subjects

Having GIS experience does not necessarily mean good understanding of the operators. It's merely an indication of spatial training and awareness. None of the respondents from the German language group had used gvSIG software and only one respondent from the Portuguese language group was familiar with gvSIG software. However, it was very unlikely that anybody knew the topological extension of gvSIG because it was available only for a short time.

4. RESULTS

The results of the human subject testing from the native speakers of the two languages are presented in a simple form of two aspects for each language group. The tables with all the details about participants' answers can be found in appendices (appendix 2 and appendix 3). The two aspects of the results are the scores of understanding of the subjects for each operator according to gvSIG implementations and the scores of subject understanding of all the operators as implemented by the gvSIG. In the tables that shows the subjects' understanding of all the operators in gvSIG as implemented by the system designer P1, P2, etc (Table 8) and GI, G2, etc (Table 9) represents individual subjects of Portuguese and German language groups respectively. The Portuguese language group is presented in the tables (Table 7 and Table 8). The German language group is also presented in the tables (Table 9 and Table 10).

gvSIG operators	Number of subjects with same answer as gvSIG	Operator score (%)	Operators average score (%)
The geometries of A must be contained by the geometries of B.	0	0	6
The geometries of A must be covered by the geometries of B.	0	0	
Each geometry in A must have an equivalent geometry in B.	5	19	
Each geometry of A must contain a geometry of B.	7	27	
Each geometry of A must cover a geometry of B.	1	4	
Each geometry of A must intersect a geometry of B.	0	0	
The geometries of A and B must be disjoint.	0	0	
Each geometry of A must touch one geometry of B.	0	0	
Each geometry of A must be covered by one or more geometries of B.	0	0	

Table 7: Scores of understanding of subjects for each operator in the Portuguese language group

Subject	Number of operators understood the same as gvSIG	Subject score (%)
P1	2	22
P2	0	0
P3	0	0
P4	0	0
P5	0	0
P6	0	0
P7	0	0
P8	1	11
P9	0	0
P10	0	0
P11	2	22
P12	0	0
P13	0	0
P14	0	0
P15	3	33
P16	1	11
P17	1	11
P18	0	0
P19	2	22
P20	0	0
P21	0	0
P22	1	11
P23	0	0
P24	0	0
P25	0	0
P26	1	11

Table 8: Scores of Portuguese subjects understanding for all the operators in gvSIG

Subject	Number of operators understood the same as gvSIG	Subject score (%)
G1	1	11
G2	2	22
G3	0	0
G4	0	0
G5	2	22
G6	2	22
G7	2	22
G8	1	11
G9	0	0
G10	2	22
G11	2	22
G12	3	33
G13	2	22
G14	1	11
G15	1	11
G16	0	0
G17	0	0
G18	0	0
G19	2	22
G20	1	11
G21	0	0
G22	2	22
G23	0	0
G24	0	0
G25	0	0
G26	1	11

Table 9: Scores of German subjects understanding for all the operators in gvSIG

gvSIG operators	Number of subjects with same answer as gvSIG	Operator score (%)	Operator average score (%)
The geometries of A must be contained by the geometries of B.	0	0	12
The geometries of A must be covered by the geometries of B.	0	0	
Each geometry in A must have an equivalent geometry in B.	13	50	
Each geometry of A must contain a geometry of B.	11	42	
Each geometry of A must cover a geometry of B.	2	8	
Each geometry of A must intersect a geometry of B.	0	0	
The geometries of A and B must be disjoint.	0	0	
Each geometry of A must touch one geometry of B.	0	0	
Each geometry of A must be covered by one or more geometries of B.	1	4	

Table 10: Scores of understanding of subjects for each operator in the German language group

From the results tables above, in Portuguese language group the subject highest score is 33% (Table 8) and only one subject got it. More than half of the subjects did not have the same understanding as gvSIG developers. The highest topological operator score is 27% (Table 7) and 6 out of 9 operators were not recognized at all. The average percentage for the topological operators is 6%.

In the German language group, the subject highest score is also 33% (Table 9) and only one subject got it. Less than 50% of the subjects did not have the same understanding as the gvSIG developers. The highest topological operator score is 50% (Table 10) and 5 out of the 9 operators were not recognized at all. The average percentage for the topological operators is 12%.

4.1 Discussion

The observed results show that, subjects from both language groups have low understanding of the topological operators of gvSIG software. This indicates a huge problem in the usability of the topology extension for gvSIG. The usability is good if people understand the operators' implementation of the system in exactly the same way as the system designer. The highest recognition rate for operator in the German and Portuguese language groups are 50% and 27% respectively. Other operators are below the mentioned percentage figures and 4 out of 9 operators (German language group) and 6 out of 9 operators (Portuguese language group) were not recognized at all (0%). The required percentage figure for operators name to be considered good is still not established. However, Riedemann (2005b) assumed a good operator name should have its implementation understood by more than 50% of its users or preferably higher.

The average operator's percentage is also very low in both language groups (Figure 9). This is consistence with the findings of the study by Riedemann (2005b) in which she obtained average operators score of below 50% in other tested GIS products for region-region relations. She concluded that majority of the users do not interpret GIS operator names in the same way as implemented in the system designers. Following these observations, gvSIG would have to modify their existing operators or change operator implementations to suite the user's needs.

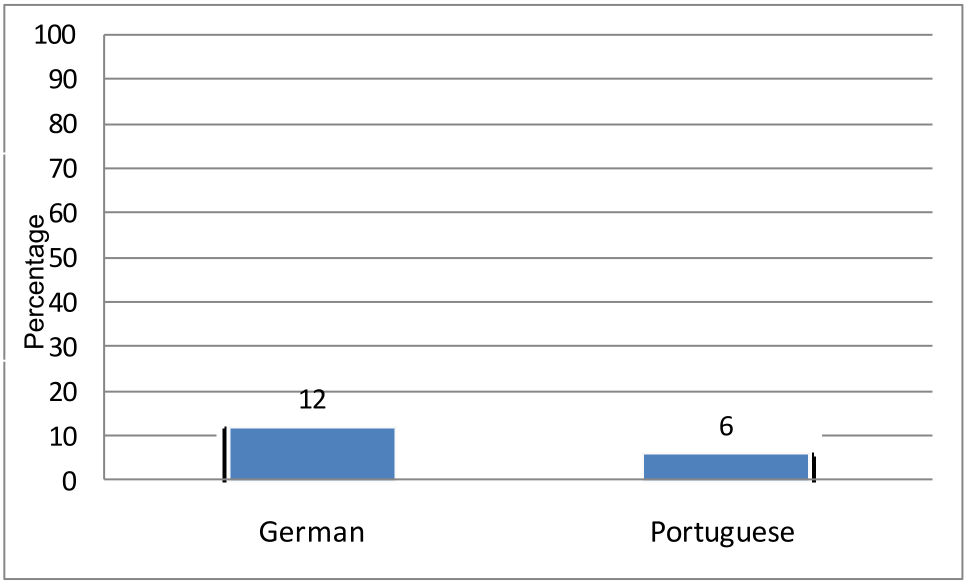


Figure 9: Operators' average score percentage for German and Portuguese

The composition of the natural language in the operator can be another factor for low operator understanding results. The operators are composed of complex sentences (e.g. *Each geometry of A must be covered by one or more geometries of B.)* I encountered cases where subjects had difficulties in understanding the word geometry/geometries. Probably gvSIG would need to eliminate the words like "*each geometry of*…" or "*all geometries of*…" in the operators and use plain words like "*A must be contained by B*",

It is observed (Figure 10) that all operators that do not implement any line-region relations seem to have at least some scores from both native speakers of Portuguese and German. This can be an indication that some operators are understood by the users in the same way as gvSIG implementation and therefore need some improvement because the same operators can also be used in other topological relations (e.g. region-region) in which gvSIG has implemented also. Many of other operators that implement line-region relations scored zero percentage in the subjects of both languages which means subjects from both native speakers of German and Portuguese were not in the same line as the gvSIG system designer.

When the gvSIG operators were compared with OGC[7] standard in the conclusion section, it was found that among the same operators that have highest recognition rate in gvSIG were also found to exist in the OGC standard. The two operators with the highest recognition rate are *Contains* for Portuguese language group (*Each geometry of A must contain a geometry of B*-in gvSIG) and *Equal* for German language group *(Each geometry in A must have an equivalent geometry in B.-in gvSIG)* and have the same operator implementations for line-region relations in both gvSIG and OGC standard. Both operators *Equivalent* and *Equal* have the same meaning but in gvSIG used as *Equivalent* and *Equal* in OGC standard. This observation suggests gvSIG to use the operators given in the OGC standard perhaps they have higher usability.

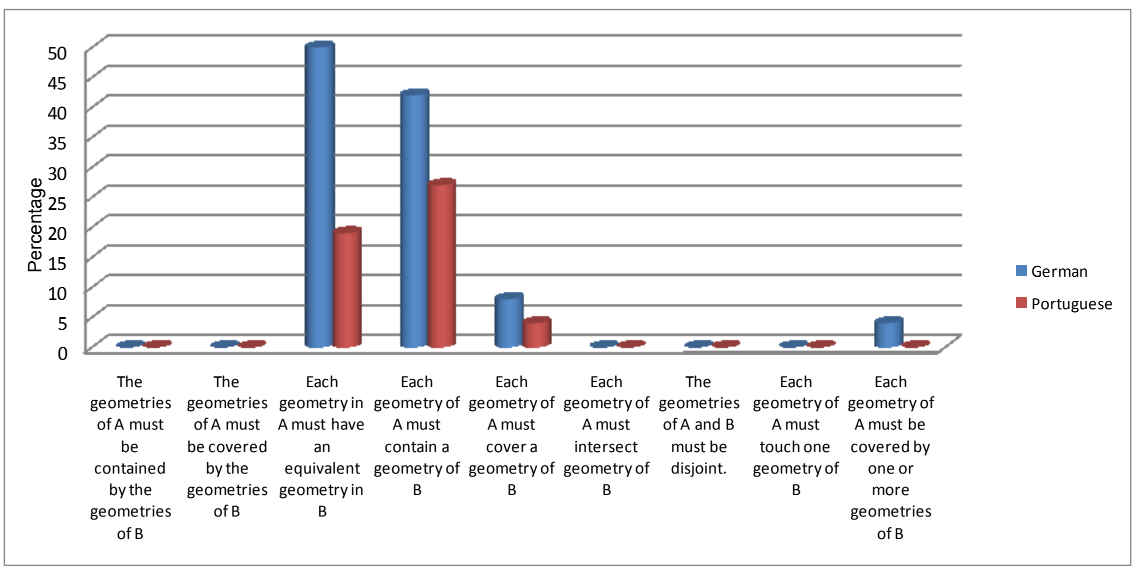


Figure 10: The percentage scores of operators from German and Portuguese subjects

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[7] OGC (Open Geospatial Consortium, Inc) is an international industry consortium of **395** companies, government agencies and universities participating in a consensus process to develop publicly available interface standards.

The German subjects seem to outscore the Portuguese subjects (Figure 10) and that means they have relatively higher understanding of operators more like gvSIG implementations compared to Portuguese subjects. However the difference is not much and all the two language groups fall under low understanding of the topological operator of the gvSIG. Both age and GIS experience showed no correlation with the subjects' answers that are the same as gvSIG operators' implementations. There is no correlation even for subjects that used more than one GIS application with those that use only one GIS application (Table 5) in both language groups though German language group has a larger composition of subjects that used more than one GIS application (Figure 11).

Language group	Correlation value
German	0.07922079
Portuguese	0.2973402

Table 11: Correlation of number of GIS application used to subject responses for German and Portuguese groups

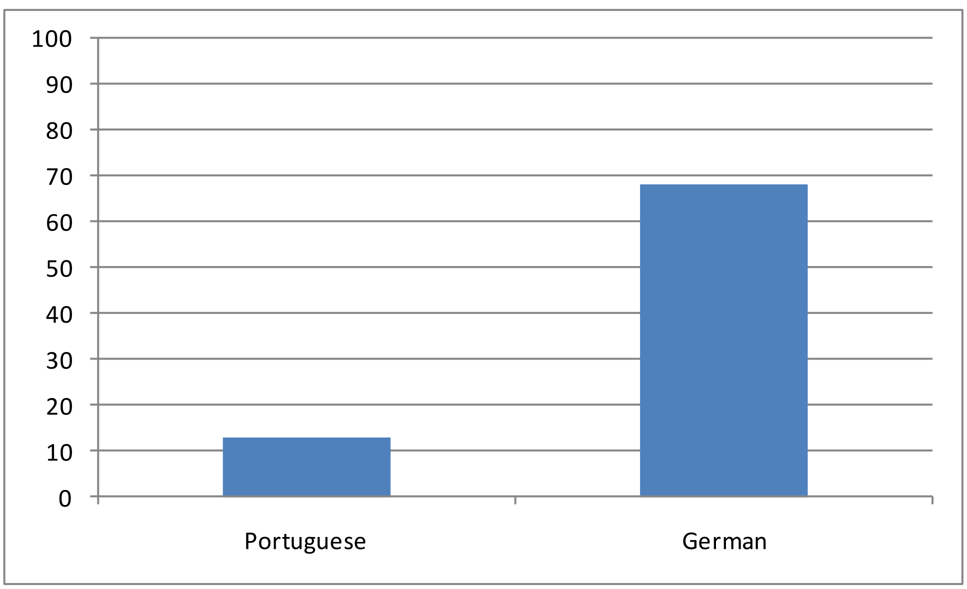

Figure 11: Subjects that used more than one GIS application.

The scientific reason for the variations between the results of the German and Portuguese language group is not known. It could be that German native speakers have outscored the Portuguese ones by chance or specific studies with many different native speakers from different languages can be done to find the variations.

Due to low understanding of gvSIG operators' implementations by the two language groups, the results was further analyzed and it was observed that there is overlapping of the subjects' results from the gvSIG implementations. Subjects from both languages considered more topological line-region configuration as applicable to topological operator.

One of the noticed patterns in the line-region configuration that was mentioned by subjects of both language groups are line-region relations with number combination (4,8,9,10,11,12,13) for the operator *"The geometries of A must be contained by the geometries of B"* (Table 12). In the gvSIG the implemented line-region relation for this operator is only (9) but there are many combinations that have (9) and other numbers as shown in the appendix 2 and 3.

	German subjects	Portuguese subjects
Count for combination (4,8,9,10,11,12,13)	10	14

Table 12: Frequency of (4,8,9,10,11,12,13) combination in Portuguese and German groups

The mentioned combination is another indication that the users consider the boundary as part of the region. There are other number combinations that a miss few numbers of the combination (4,8,9,10,11,12,13) but include 9. All these fall in the same category of boundary inclusion. In order to fulfill the gvSIG implementation the words in the operator should explicitly indicate that the boundary is not included as part of B or change the implementations if the boundary is part of B.

All the subjects in both languages answered (1) for the operator *“the geometries of A and B must be disjoint”*. In gvSIG the implemented line-region relations is the number combination (1,3). The subjects in both language groups chose (1). In Table 13 are results for those that mention exactly (1) but other subjects with other combination chose the same. The subjects have chosen (3) which are implemented in gvSIG in other operators including in the operator *“Each geometry of A must intersect geometry of B”* in which gvSIG did not implement line-region relation number (3).

	German subjects	Portuguese subjects
Count for combination (1)	16	16

Table 13: Frequency of combination (1) for Portuguese and German groups

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5. CONCLUSIONS

Usability testing is very important for the development of the software life cycle and users' need is the goal of a serious software engineer. If users fail to understand the functions in the software, its existence is virtually meaningless. This study tested the understanding of the human subjects (German and Portuguese native speakers) on the existing gvSIG topological extension operators using the line-region relations of the Egenhofer "*9- intersection model*". Only small fraction of the respondents from both languages groups (6% average operators in Portuguese and 12% average operators in German) reported to be comfortable with gvSIG operators which indicate that the usability of gvSIG topological extension is very low. This necessitates making changes in the operators or its implementations.

The gvSIG topological extension low usability could be caused by various things that have been noted in this study:

- It appeared that the gvSIG operators are composed of complex sentences that could make the subjects to fail to match the operator implementation as that of gvSIG software. The simple sentences could possibly increase its usability. For example, it would be interesting to see subjects reactions if the natural languages used in gvSIG would eliminate the words like "*each geometry of*…" or "*all geometries of*…" in the operators and use plain words like "*A must be contained by B*", the gvSIG operators used words like "*the geometries of A must be contained by the geometries of B*". I often encountered subjects to have difficulties on understanding the word geometry/geometries during the conduction of the questionnaire.

- The subjects seem to consider more topological line-region configurations as applicable to the topological operator. Therefore did not have the same understanding as gvSIG operators' implementations. And further more it was observed from some patterns in the subjects' answers that the subjects tend to include the boundary as part of the region. Changing of the gvSIG operator implementations would accommodate the users' needs.

Perhaps the low usability of gvSIG topology extension can be increased by following the standards of OGC[8] on the Operators implementation since it is a responsible International organ for developing interface standards. The operators that have higher recognition rate in the tested subjects in gvSIG also exists in OGC and have the same implementations in both (gvSIG and OGC) this suggests further using OGC standard would probably increase the usability of gvSIG topology extension.

There are differences between the operators used in gvSIG and those of OGC. The operators put forward by OGC are; equals, disjoint, intersects, touches, overlaps, crosses, within and contains. In the gvSIG the operators are; cover/covered, touch, intersect, disjoint and contain/contained and equivalent. Some of the operators in gvSIG (e.g. cover/covered) are not at all in the OGC operator standard which means its standard on the implementation is not existing. Others can be related for example *Equivalent* in gvSIG can be related to *Equal* in the OGC. The choices of operators' names have an effect in the way they are understood by the users. This has been shown in Riedemann (2005b) study. Other gvSIG operators are similar to the ones in OGC and therefore can

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[8] OGC (Open Geospatial Consortium, Inc) is an international industry consortium of **395** companies, government agencies and universities participating in a consensus process to develop publicly available interface standards.

be compared to the OGC standard to see the differences and commonalities of their implementation for the19- line-region relations of the Egenhofer 9-intersection model. The similar operators are touches, disjoint, contain and intersect. The commonalities and differences of gvSIG and OGC similar operators' implementations are presented in the tables below.

In this operator comparison between gvSIG and OGC, "A" represents a line while "B" represents a region. Only line-region relations are use in the comparison. The conditions for the operators implementation are according to OGC (2006).

- Touches

In the OGC standard the *touch* relationship for the two geometric objects "A" and "B" applies to Area/Area, Line/Line, Line/Area, Point/Areas and Point/Line. This relationship is not applicable to Point/Point.

A touches B should meet the following condition according to OGC.

A. Touch (B) $\Leftrightarrow$ $(I(A) \cap I(B) = \emptyset) \wedge (A \cap B) \neq \emptyset$ where (I) is the interior of the geometric object.

Table 14 shows the comparison of *touch* operator implementation for line-region relation in gvSIG and OGC.

	line-region number combination
gvSIG	
OGC	2,3,4,5,6,7

Table 14: Comparison of *touch* operator implementation for line-region relations in gvSIG and OGC

From Table 14, it shows that no relation is implemented in the gvSIG but the OGC which is the international standard for user interfaces says line-region relation number 2,3,4,5,6 and 7 are implemented for the touch operator.

- Disjoint

In the OGC standard, the *disjoint* relationship for the two geometric objects “A” and “B” should meet the following condition.

A. Disjoint (B) $\Leftrightarrow$ A $\cap$ B = Ø

Table 15 shows the comparison of *disjoint* operator implementation for line-region relation in gvSIG and OGC.

	line-region number combination
gvSIG	1,3
OGC	1

Table 15: Comparison of *disjoint* operator implementation for line-region in gvSIG and OGC

From Table 15, it shows that gvSIG have one more line-region relation (3) as compared to OGC.

- Contains

In OGC standard the *Contains* relationship for two geometric objects “A” and “B” should meet the following condition

A. Contains (B) $\Leftrightarrow$B. Within (A)

A. Within (B) $\Leftrightarrow$ (A$\cap$B=A) ^ (I (A) $\cap$E (B) =Ø) where (I) is the interior and (E) exterior of the geometric object.

Table 16 shows the comparison of *contains* operator implementation for line-region relation in gvSIG and OGC.

	line-region number combination
gvSIG	
OGC	

Table 16: Comparison of *contains* operator implementation for line-region in gvSIG and OGC

From Table 16, shows that gvSIG and OGC have not implemented any relation. The two have similar implementation and therefore, gvSIG meets OGC standard. The Contains operator has the highest recognition rate in Portuguese subjects and ranks the second in the German subjects for the two tested language groups.

- Intersects

In OGC standard, *intersects* relationship for two geometric objects "A" and "B" should meet the following condition.

A. intersects (B) ⇔ ! A. Disjoint (B) or more clearly the inverse of A. Disjoint (B)

Table 17 shows the comparison of *intersects* operator implementation for line-region relation in gvSIG and OGC.

	line-region number combination
gvSIG	2,4,5,6,7,8,10,11,12,13,14,15,16,17,18,19
OGC	2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19

Table 17: Comparison of *intersects* operator implementation for line-region in gvSIG and OGC

From Table 17, it shows that gvSIG are missing line-region relations number (3) and (9) so they differ from the OGC.

The OGC equal operator will also be compared to the equivalent of gvSIG because equal relates with equivalent.

- Equals

In OGC standard the *Equals* relationship for two geometric objects "A" and "B" should meet the following condition.

A. Equals (B) $\Leftrightarrow A \subseteq B \wedge B \subseteq A$

Table 18 shows the comparison of *Equals* operator implementation for line-region relation in gvSIG and OGC.

	line-region number combination
gvSIG	
OGC	

Table 18: Comparison of *Equals* operator implementation for line-region relation in gvSIG and OGC

From Table 18, shows that gvSIG and OGC have not implemented any relation. The two have similar implementation and therefore gvSIG meets OGC standard. But probably one of the two names are preferred by users that the other. Equivalent operator has the highest recognition rate in the German language group for the tested subjects.

From all of the 5 similar operators only two the implementations of two operators are according to the OGC standards. Other operators used in gvSIG example cover are not in the OGC standard list. If gvSIG could follow the OGC standard might increase its usability.

5.1 Recommendations and Future work

The low usability of the gvSIG operators needs to be worked on so that to achieve the user's needs. From the findings obtained from this study several recommendations are put forward:-

- gvSIG could use simple sentences in its operators as some respondents had problem understanding some of the words used in the operators like geometry/geometries.
- It was found that some respondents considered more topological line-region relation configurations as applicable to the topological operator; therefore changing the implementation of the operator could help win the users.
- It was observed from the subjects' answers that a good number of respondents treated a boundary a part of the region. This is important

finding especially when choosing or forming the words to use in the operators.

- It was found that some gvSIG operators have different implementation as those of the OGC, which is the International standard for the user interfaces. Using OGC standard for the implementation of the operators could increase the usability of gvSIG topology extension.

Fortunately, gvSIG topology extension (alpha) is currently under development thus the proposed changes can easily be incorporated. Similarly, the findings of this study can provide useful insights as to the terms to be used in translating the operator to other languages.

Further study and research on the gvSIG operator implementation of topological relations of other geometric objects such as regions, lines and points is indeed needed. The subjects' group could also be increased to include other languages as gvSIG software has multilingual user interface. Also the testing of human subject on the understanding of operators used in OGC standards could be established.

5.2 Limitations

This study had several short comings: - The region diagram in the questionnaire was not explicitly explained in the first round of sending questionnaire. Only few subjects understood it in the intended way. The first results showed subject interpreted red circle as a closed line with a hole and not a region. The questionnaires of the subjects with answers that interpreted red circle as closed line with a hole were identified and questionnaire re-sent but this time was demonstrated in the first page that the red circle is a region and the blue one is a line. At times it was sent to a different subject if the original ones did not return the feedback. The instructions were also added in the email during sending emphasizing the same plus extra information insisting that there is no hole in the red circle (region). About 75% of German questionnaires and 65% of the Portuguese questionnaires were re-sent respectively. This indicates that a good number of the respondents that had misunderstanding were sent with proper instructions in the second round. After the collection of the questionnaires for the second time, it was clear that none of the respondent treated for example a blue line inside a red circle (region) as disjoint. However, some of incorrect answers could have been caused by the effect of this error. A shading of the interior of red circle (region) could have clearly represented a graphical representation of the region. This could have minimized a lot of instructions given to the respondents. However, due to time constraint and the fact that respondents were contacted by email and some with slow response from the two sample groups located in different geographical locations (Germany and Portugal). Therefore, it was resolved that this method would be quicker and enable the completion of study.

The minimum required number was 30 questionnaires for each language group but instead 26 questionnaires that were obtained from volunteered respondents were used for analysis. Generally more that 30 questionnaires in each language group were sent but the returned questionnaires for each language group were 26.

One respondent made a comment that the resolution of the diagram was low making it hard to decide in some line-region relations.

The gvSIG operators were originally in Spanish and had to be translated to English first and then to German and Portuguese to be used in the questionnaire in German language group and Portuguese one respectively.

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APPENDICES

1. Explanation on interpreting the results in appendix 2 and 3

In each appendix (appendix 2 and 3) the number combination e.g. (1,2,3,4,6) of line-region relations (see the graphical figures and the assigned number in Table 1) implemented by gvSIG are presented in the gvSIG rows (shaded). The number combination is separated by comma if more than one line-region relations are implemented. The cell/box in the table is left blank if no line-region relation is implemented. For appendix 2, the P1 to P26 represents each separate Portuguese subject tested for each operator (e.g. *the geometries of A must be contained by the geometries of B.*) and their answers (number combination) are put in the box of each respective operator. The same applies for appendix 3 where G1 to G26 represents each separate Germany subjects tested.

The results are considered correct (have the same operator implementation as that of the gvSIG) if the line-region number combination of the subject exactly matches those of the gvSIG otherwise wrong answer. Table 19 gives an example on how the subjects obtain a correct or wrong answer according to the gvSIG software implementation. The number combinations used in the table are only example values to explain how the correct answers are obtained.

Operators	The geometries of A must be contained by the geometries of B.	The geometries of A must be covered by the geometries of B.	Each geometry in A must have an equivalent geometry in B.	Each geometry of A must contain a geometry of B.
gvSIG implementation	2,5,7,9,10	4,5,7,10	9	
Subject answers (G1,G2 etc or P1,P2 etc)	2,5,7,9,10	2,3,7,10	9	5,12
Answers	**Correct**	**Wrong**	**Correct**	**Wrong**

Table 19: Example on how to obtain the valid answer according to gvSIG

2. Results of Portuguese native speaker subjects

	The geometries of A must be contained by the geometries of B.	The geometries of A must be covered by the geometries of B.	Each geometry in A must have an equivalent geometry in B.	Each geometry of A must contain a geometry of B.	Each geometry of A must cover a geometry of B.	Each geometry of A must intersect geometry of B.	The geometries of A and B must be disjoint.	Each geometry of A must touch one geometry of B.	Each geometry of A must be covered by one or more geometries of B.	**Subject score (%)**
gvSIG	**9**	**9**				**2,4,5,6,7,8,10,11,12,13,14,15,16,17,18,19**	**1,3**		**9**	
P1	4,8,9,10,11,12,13	8,10,12,14,15,16,17,18,19			14,15,16,17,18,19	2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19	1	2,3,4,5,6,7,8,10,11,12,13	8,10,12,14,15,16,17,18,19	**22**
P2	4,8,9,10,11,12,13	4,8,9,10,11,12,13	4,5,6,7,8,9,10,11,12,15,18,19	4,8,9,10,11,12,13	4,8,9,10,11,12,13	6,14,16,17,18	1,4,8,10,11,12,13	3,4,5,7,9,11,12,13,14,15,16,19	4,8,9,10,11,12,13	**0**
P3	4,8,9,10,11,12,13	4,8,9,10,11,12,13	2,4,17	2,4,11,13,17	4,8,9,10,11,12,13	6,7,14,16,b,18,19	1,2,3,5	2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19	4,8,9,10,11,12,13	**0**
P4	9,10,11,12,13,14,15,16,17,18,19	4,8,9,10,11,12,13,14,15,16,17,18,19	2,3,4,5,6,7,8,10,11,12,13,14,15,16,17,18,19	2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19	4,8,9,10,11,12,13,14,15,16,17,18,19	16,8,14,15	1	2,3,4,6,7,8,9,10,11,12,13,14,15,16,17,18,19	1,2,3,8,9,10,11,12,13,14,15,16,17,18,19	**0**
P5	4,8,9,10,11,12,13	4,8,9,11,12,13	4,8,9,10,11,12,13	2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19	2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19	2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19	1	2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19	4,8,9,10,11,12,13	**0**
P6	4,8,9,10,11,12,13	4,9,10,12,13	4,8,9,10,11,12,13	3,4,9,10,11,12,13	2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19	2,3,5,6,7,14,15,16,17,18,19	1	2,3,13	4,8,9,10,11,12,13	**0**
P7	4,6,8,10,11,12,13	4,6,7,8,10,11,12,13,14,15	4,5,6,7,11,12,13	4,8,9,10,11,12,13,14,15,16,18,19	4,8,9,10,11	11,14,15,16,17,18,19	1	4,8,9,10,11,12,13	4,8,9,10,11,13	**0**

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P8	8,9,10,12,13	4,8,9,10,11,12,13	4,8,9,10,11,12,13		4	4,5,6,8,10,11,14,16,17,18,19	1	2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19	4,8,9,10,11,12,13	**11**
P9	2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19	4,6,8,7,9,10,11,12,13,14,15,16,17,18,19	2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19	1,2,3,4,5,6, 7, 8,9,10,11,12, 13,14, 15,16,17,18,19	4,6,7,8,9,10,11,12,13,14,15,16,17,18,19	2,3,4,5,6,7,8,10,11,12,13,14,15,16,17,18,19	1	2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19	4,8,9,10,11,12,13	**0**
P10	4,8,9,10,11,12,13,14,15,16,18,17,19	2,3,4,5,6,8,9,10,11,12,13,14,15,16,17,18,19	2,4,5,6,11,12,13,15,17,19	4,8,9,10,11,12,15,16,17,18,19	6,15,19	3,8,10,11,12,13,14,15,16,17,18,19	1,3,6,15,19	2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19	8,9,10,11,12,13,14,15,16,17,18,19	**0**
P11	9,12				4	16,17,18	1	2,3,4,5,6,7,8,10,11,12,13,14,15,16,17,18,19	4	**22**
P12	8,9	3,4,5,6,7,8,9,10,11,12,13,14,16,17,18,19	4,8,9,10,11,12,13	4,8,9,10,11,12,13	4,9,10,11,12,13	4,8,9,10,11,12,13	1	4	4,8,9,10,11,12,13	**0**
P13	4,9,10,11,12,13	4,8,9,10,11,12,13	4	4,8,9,10,11,12,13,	4,8,9,10,11,12,13	4,8,9,10,11,12,13	1	4,8,9,10,11,12,13	4,8,9,10,11,1213	**0**
P14	4,8,9,10,11,12,13	4,9,11,13	4,6,7,11,13	5,6,7,11,12,13	4,5,7,9,11,12,13	3,7,11,12,13,14,15,16,17,18,19	1	2,4,8,9,10,12,13,15	4,8,9,10,11,12,13	**0**
P15	4,8,9,10,11,12,13	2				3,4,5,6,7,8,10,11,12,13,14,15,16,17,18,19	1,2	2,3,4,5,7,8,10,11,12,13,14,15,16,17,18,19	4	**33**
P16	4,8,9,10,11,12,13	4,8,9,10,11,12,13	4,8,9,10,11,12,13	4,8,9,10,11,12,13	4,8,9,10,11,12,13	2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19	1	4,8,9,10,11,12,13	4,8,9,10,11,12,13	**11**
P17	4,8,9,10,12		4,11,13		4,5,7,11,13	14,15,16,17,18,19	1	2,3,4,5,6,7,8,10,11,12,13,14,15,16,17,18,19		**11**

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P18	4,8,9,10, 11,12,13	4,8,9,10, 12,13	2,4,12, 17	2,3,4,5,6, 7,8,9,10, 11,12,13, 14,15,16, 17,18,19	4,8,9,10, 11,13	4,8,9,10,11, 12	1,3, 5,6, 7,9, 10, 11, 13, 14, 15, 16, 18, 19	2,3,4,5,6, 7,8,9,10, 11,12,13, 14,15,16, 17,18,19	4,8,9,10, 11,12,13	**0**
P19	4,8,10,1 1,12,13	4,8,9,10, 11,12,13			4,8,9,10, 11,12,13	2,3,4,5,6,7,8, 9,10,11,12, 13,14,15,16, 17,18,19	1	2,3,4,5,6, 7,8,10,11, 12,13,14, 15,16,17, 18,19	4,8,9,10, 11,12,13	**22**
P20	4,8,9,10, 11,12, 13,14, 15,16, 17,19	4,8,9,10, 11,12, 13,14, 15,16, 17,18,19	4,5,6, 7,8,9, 10,11, 12,13, 14,15, 16,18, 19	4,5,6,7,8, 9,10,11, 12,13,14, 15,16,17, 18,19	4,8,9,10, 11,12,13, 14,15,16, 18,19	2,4,5,6,7,8,9, 10,11,12,13, 14,15,16,17, 18,19	1	2,3,4,5,6, 7,8,9,10, 11,12,14, 15,16,17, 18,19	4,8,9,10, 11,12,13	**0**
P21	4,8,9,10, 11,12,13	4,8,9,10, 11,12,13	4,6,7, 11,12, 13	3,4,5,6,7, 8,9,10, 11,12,13, 15,16,17, 18,19	4,5,6,7,8, 9,10,11, 12,13,14, 15,16,17, 18,19	3,4,5,6,7,8,9, 10,11,12,13, 14,15,16,17, 18,19	1	2,3,4,5,6, 7,8,9,10, 11,12,13, 14,15,16, 17,18,19	4,8,9,10, 11,12,13	**0**
P22	4,8,9,10, 11,12,13	4,5,6,8, 9,10,11, 12,13,19		4	4	2,3,4,5,6,7,8, 10,13,14,15, 16,17,18,19	2,4, 6,7, 8, 13, 14, 15, 16, 7,19	3,4,5,6,7, 8,10,11, 12,14,16, 17,18,19	3,4,6,8,9, 10,11,12, 13	**11**
P23	4,8,9,10, 11,12,13	4,8,9,10, 11,12,13	4,5,6,7 ,8,9,10 ,11,12, 13,15, 16,17, 19	4,5,7,8,1 1,12,13	4,5,6,7,8, 9,10,11,1 2,13,14,1 5,16, 17	2,3,5,6,7,8, 11,12,13,14, 15,16,17,18, 19	1,5	3,10,18	4,8,9,10, 11,12,13	**0**
P24	4,8,9,10, 11,12,13	4,8,9,10, 13	4,8,9, 10,11, 13	4,8,9,10, 11,13,16	4,6,8,9, 10,11,12, 13,	2,3,4,7,8,9, 10,11,12,13, 14,15,16,17, 18,19	1,2, 3,5, 6,7, 10, 14, 15, 16, 17, 18, 19	2,3,4,5,6, 7,8,9,10, 11,12,13, 14,15,16, 17,18,19	4,7,8,9, 10,11,13	**0**

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P25	4,8,9,10, 11,12,13	4,5,8,9, 10,11, 12,13	4,5,11, 12,13	4,8,9,10, 11,12,13	4,8,9,10, 11,12,13	2,3,4,5,6,7,8, 10,11,12,13, 14,15,16,17, 18,19	1,9	2,3,4,5,6, 7,8,10,11, 12,13,14, 15,16,17, 18,19	4,7,8,9, 10,11,12, 13	**0**
P26	4,8,9,10, 11,12, 13,14, 15,16, 17,19	4,6,8,9,1 0,11,12, 13,14, 15,16, 17,18,19	4,6,7, 8,9,10, 11,12, 13,14, 15,16, 17,18, 19		7,8,9,10, 11,12,13, 14,15,16, 17,18,19	4,6,7,8,9,10, 11,12,13,14, 15,16,17,18, 19	1,2, 3	2,4,6,7,8, 9,10,11, 12,13,14, 15,16,17, 18,19	4,6,7,8,9, 10,11,12, 13,14,15, 16,17,18, 19	**11**
Operator score (%)	**0**	**0**	**19**	**27**	**4**	**0**	**0**	**0**	**0**	

3. Results of German native speaker subjects

	The geometries of A must be contained by the geometries of B.	The geometries of A must be covered by the geometries of B.	Each geometry in A must have an equivalent geometry in B.	Each geometry of A must contain a geometry of B.	Each geometry of A must cover a geometry of B.	Each geometry of A must intersect geometry of B.	The geometries of A and B must be disjoint.	Each geometry of A must touch one geometry of B.	Each geometry of A must be covered by one or more geometries of B.	**Subject scores (%)**
gvSIG	**9**	**9**				**2,4,5,6,7,8, 10,11,12,13, 14,15,16, 1718,19**	**1,3**		**9**	
G1	4,8,9, 10,12, 15	4,5,6,7, 8,9,10, 11,12, 13,14, 15,16, 17,18,19		13	2,3,4,5,6, 7,8,9,10, 11,12,13, 14,15,16, 17,18,19	2,3,4,5,6,7,8 ,9,10,11,12, 13,14,15,16, 17,18,19	1	2,3,4,5, 6,7,8,9, 10,11, 12,13, 14,15, 16,17,18 ,19	3,4,5,6,7,8 ,9,10,11, 12,13,14, 15,16,17, 18,19	**11**
G2	4,8,9, 10,11, 12,13	2,3,4,5, 6,7,8,9, 10,11, 12,13, 14,15, 16,17, 18,19			2,3,4,5,6, 7,8,9,10, 11,12,13, 14,15,16, 17,18,19	2,3,4,5,6,7, 8,9,10,11, 12,13,14,15, 16,17,18,19	1	2,3,4,5, 6,7,8,9, 10,11, 12,13, 14,15, 16,17, 18,19	2,3,4,5,6,7 ,8,9,10,11, 12,13,14, 15,16,17, 18,19	**22**
G3	4,8,9 ,10,11, 12,13	4,6,7,8, 10,11, 12,13, 14,15, 16,17, 18,19	4,5,12	4,5,6, 7,11, 12,13, 15	2,4,6,8, 10,11,12, 13,14,15, 16,17,18, 19	2,3,5,7,8,10, 11,12,14,15, 16,17,19	1	2,3,4,5, 6,7,8,10, 11,12, 13,14, 15,16, 17,18,19	2,3,4,5,6, 7,10,11, 12,13,14, 15,16,17, 18,19	**0**
G4	4,8,9, 10,11, 12,13	4,6,7,8, 9,10,11, 12,13, 14,15, 16,18,19	4	4,8,9,1 0,11,1 2,13	4,8,9,10,1 1,12,13	3,4,5,6,8,9, 10,11,12,13, 14,15,16,17, 18,19	1	2,3,4,5, 6,7,8,9, 10,11,12 ,13,14, 15,16, 17,18,19	4,6,8,9,10, 11,12,13	**0**
G5	4,8,9, 10,11, 12,13	4,6,7,8, 9,10,11, 12,13, 14,15, 16,17, 18,19			4,6,7,9,10, 11,12,13, 14,15,16, 17,18,19	14,15,16,17, 18,19	1,2,3,5, 6,7,8,9, 10,11, 13,14, 15,16, 17,18, 19	3,4,7	4,8,9,10, 11,12,13	**22**

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G6	3,4,6, 7,8,9, 10,11, 12,13, 14,15, 16,17, 18,19	3,4,5,6, 7,9,10, 12,13, 14,15, 16,17, 18,19			3,4,5,6,7, 8,10,11, 12,13,14, 15,17,18, 19	3,4,5,6,7,8, 10,11,12,13, 15,16,17,18, 19	1,2	2,3,4,5, 6,7,8,9, 10,11, 12,13, 14,15, 16,17, 18,19	3,4,5,6,7,8 ,9,10,11, 12,13,14, 15,16,17, 18,19	**22**
G7	4,8,9, 10,11, 12,13	4,8,9,10, 11,12, 13,14, 15,16, 17,18,19			4,5,6,10, 11,12,13, 14,15,16, 17,18,19	3,4,5,6,7,8, 9,10,11,12, 13,14,15,16, 17,18,19	1,2	3,4,5,6,7 ,10	4,8,9,10, 11,12,13	**22**
G8	4,8,9, 10,11, 12	4,8,9,10, 11,12,13	4,6,7, 11,13	3,4,5, 6,7,8, 9,10, 11,12, 13,14, 15,16, 18,19		7,8,9,10,11, 12,13,14,15, 16,17,18,19	1	2,3,4,5, 6,7,8,9, 10,11, 12,13, 14,15, 16,17, 18,19	4,8,9,10, 11,12,13, 14,15,16, 17,18,19	**11**
G9	4,9,10, 11,12, 13,19	3,4,5,6, 7,8,10, 11,12, 13,14, 15,16, 17,18, 19	8,9,10, 11,12, 13	3,4,5, 7,8,9, 10,11, 12,13, 14,16, 17,18	3,4,5,8,9, 10,11,12, 14,16,17, 18	3,4,5,7,8,12, 14,16,17,18	1,2	2,3,4,5, 7,8,9,10, 11,12, 13,14, 15,17, 18,19	3,4,5,7,8, 9,10,12, 14,16,17, 18	**0**
G10	8,10, 11,13	4,8,9,10, 11,12, 13,14, 15,16, 17,18,19			2,4,6,8,10, 11,12,13, 14,15,16, 17,18,19	3,4,5,6,7,8, 9,10,11,12, 13,14,15,16, 17,18,19	1,2	3,4,5,6, 7,8,10, 11,12, 13,14, 15,16, 17,18,19	4,7,8,9,10, 11,12,13, 14,15,16, 17,18,19	**22**
G11	4,8,9, 10,11, 12,13, 18	3,4,5,6, 7,8,9,10, 11,12, 13,14, 15,17, 18,19			3,4,5,6,7, 8,9,10,11, 12,13,14, 15,16,17, 18,19	4,5,7,8,10, 11,12,13,14, 15,16,17,18, 19	1	3,4,5,6, 7,8,10, 11,12, 13,14, 15,16, 17,18,19	4,8,9,10, 11,12,13	**22**
G12	8,9,10, 11,12, 13	4,5,6,7, 11,12, 13,14, 16,17				4,5,6,7,11, 12,13,14,15, 16,17,18,19	1	2,3,4,5, 6,7,8,10, 11,12,13 ,14,15,1 6,17,19	4,5,6,7,11, 12,13	**33**
G13	4,8,9, 10,11, 12,13	4,6,7,8, 9,10,11, 12,13, 14,15, 16,17, 18,19			4,8,9,10, 11,12,13	4,6,7,8,9,10, 11,12,13,14, 15,16,17,18, 19	1	2,3,4,5, 6,8,9,10, 11,12, 13,14, 15,16, 17,18,19	4,8,9,10, 11,12,13, 14,16,17, 18	**22**

Continued on the next page

Continued from previous page

G14	4,8,9, 10,11, 12,13	2,3,4,5, 6,7,8,9, 10,11, 12,13, 14,15, 16,17, 18,19		2,3,4, 5,6,7, 8,9,10, 11,13, 14,15, 16,17, 18,19	2,3,4,5,6, 7,8,9,10, 11,12,13, 14,15,16, 17,18,19	2,3,4,5,6,7, 8,9,10,11, 12,13,14,15, 16,17,18,19	1	2,3,4,5, 6,7,8,9, 10,11, 12,13, 14,15, 16,17, 18,19	2,3,4,5,6, 7,8,9,10, 11,12,13, 14,15,16, 17,18,19	**11**
G15	4		2,6,11, 13		3,4,5,10, 12,18	3,4,7,14,15, 16,17,18,19	1	2,3,4,5, 6,7,8,10, 12,13, 15,19		**11**
G16	4,8,9, 10,11, 13	5,7,14, 15,16, 17,18, 19	4	2,3,4, 7,8,9, 10,11, 12,13, 14,16, 18,19	2,3,5,10, 14,17,18	5,7,14,16, 17,18	1	2,3,5	2,3,5,7,14, 16,17,18	**0**
G17	4,8,9, 10,11, 12,13		2,3,4, 6,7,8, 9,10, 11,12, 13,14, 15,16, 17,18, 19	3,4,5, 6,7,8, 9,11, 12,13, 14,16, 17,18, 19	3,4,5,6,7, 9,10,11, 12,13,14, 15,16,17, 18,19	3,5,6,7,8,9, 10,11,12,13, 14,15,16,17, 19	1,2	2,5,19		**0**
G18	4,8,9, 10,11, 12,13	3,4,5,6, 7,8,9,10, 11,12, 13,14, 15,16, 17,18,19	4,8,9, 10,11, 12,13	4,8,9, 10,11, 12,13	3,4,5,6,7, 8,9,10,11, 12,13,14, 15,16,17, 18,19	3,4,5,6,7,9, 10,11,12,13, 14,15,16,17, 18,19	1,2	2	3,4,5,6,7, 9,10,11, 13,14,15, 16,17,18	**0**
G19	4,8,9, 10,11, 12,13	3,4,5,6, 7,8,9,10, 11,12,13 ,14, 15,16,17 , 18,19			3,4,5,6,7,8 ,9,10,11,1 2,13,14,15 ,16,17,18, 19	2,3,4,5,6,7,8 ,9,10,11,12, 13,14,15,16, 17,18,19	1,2	3,4,5,6,7 ,8,9,10,1 1,12,13, 15,16,17 ,18,19	3,4,5,6,7,8 ,9,10,11,1 2,13,14,15 ,16,17,18, 19	**22**
G20	4,8,9,1 0, 11,12, 13	4,8,9,10, 11,12, 13,14, 15,16, 17,18		2,3,4,5 ,7,8,9, 10,11, 12,13, 14,15, 16,17, 18,19	14,15,16,1 7,18,19	2,3,4,6,7,9,1 0,11,12,13,1 4,15,16,17,1 8,19	1	2,3,4,5,6 ,7,8,10,1 1,13,14, 18,19	6,14,16,17 ,18,19	**11**
G21	4,8,11, 12,13		4,12	4,6,7, 11,13	8,10,13, 14,15,16, 17,18	11,14,16	1	2,5,10, 12	4,8,9,10, 12	**0**
G22	8,9,10	6,8,9,10, 12,14, 16,17,18			4,8,9,12, 14,16,17, 18	8,9,10,12, 14,16,17,18	2,4,5,6,7	2,3,5,6,7	8,9,10,12, 14,16,17, 18	**22**

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Continued from previous page

G23	4,8,9, 10,11, 12,13	4	3,4,6, 7,10, 11,12, 13,14, 15,16, 17,18, 19	3,4,5, 6,7,11, 13,14, 15,16, 17,18	4,5,6,7,11, 12,13	5,14,15,16, 17,18,19	1	2,3,8,10	4,5,6,7,12, 13,15	**0**
G24	4,8,9, 10,11, 12,13	3,4,5,6,7 ,8,9,10, 11,12, 13,14, 16,17, 18,19	14,18	4,8,9, 10,11, 12,13	2,3,4,5,6, 8,10,11, 12,13,14, 15,16,17, 18,19	5,14	1	2,3,4,5, 6,7,8,9, 10,11, 12,13, 14,15, 16,17, 18,19	3,4,5,6,7, 8,9,10,11, 12,13,14, 15,16,17, 18,19	**0**
G25	4,8,9, 10,11, 12,13	4,5,6,7, 11,12,13	2,4,5, 12,17	4	2,3,4,5,6, 7,8,9,10, 11,12,13, 14,15,16, 17,18,19	5,8,13,14, 15,16	1	2,3,4,5, 6,7,8,9, 10,11, 12,13, 14,15, 16,17, 18,19	4	**0**
G26	4,5,12	8,9	7,4,12	4,5,12	4,5,6,7,8, 9,10,11, 12,13,14, 16,17,18, 19	4,5,6,7,8,9, 10,11,12,13, 14,15,16,17, 18,19	1,2	2,3,4,5, 6,7,8,9, 10,11, 12,13, 14,15, 16,17, 18,19	9	**11**
Operator score (%)	**0**	**0**	**50**	**42**	**8**	**0**	**0**	**0**	**4**	

4. Questionnaire

Questionnaire used in data collection (Presented in English for readability)

Instituto Superior de Estatística e Gestão de Informação
Universidade Nova de Lisboa
&
Institute for Geoinformatics
Muenster University
Questionnaire for testing the spatial operators on line-region relations for the Master thesis

Questionnaire No. QN01E

A. Interviewer information:

Please fill the following information about yourself. It takes approximately **20 minutes** to fill in this questionnaire. Please return the data to me once you have filled in the complete questionnaire.

1. Nationality ____ 2. Mother tongue language ____

3. Age ____ 4. Gender (M / F) ____ 5. Profession ____ 6. Date ____

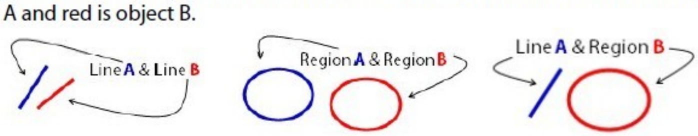
7. Do you already have experience with geographic information systems (GIS)? ☐ Yes ☐ No

8. If you have experience with GIS products, please state the product name and the language edition below

____

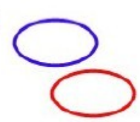
2. Instructions to fill in this questionnaire

Please, read the sentences on top of each page and indicate for each picture below, whether the sentence is applicable / not applicable to the situation shown in the picture by clicking on the small box for either **"applicable"** or **"not applicable"**. There are altogether 9 questions. Please note the matching of colors: blue is object A and red is object B.



Below is an example of how to fill the questionnaire.

1. Every geometry of **A** must share a common point with a geometry of **B**.

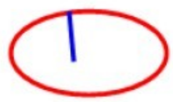
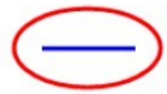
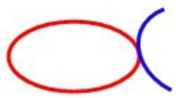
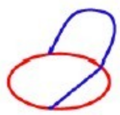
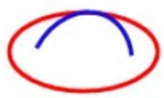
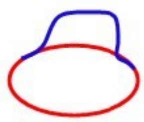
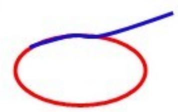
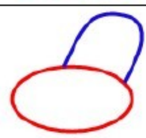
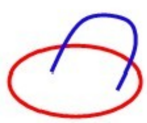
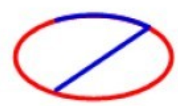
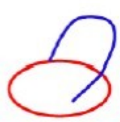
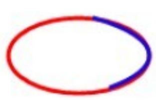
(1)		(2)	
	☐ applicable ☒ not applicable		☐ applicable ☒ not applicable

3. Sending (returning) the filled questionnaire electronically (data)

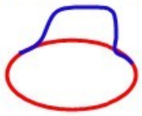
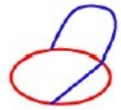
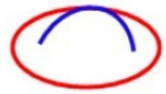
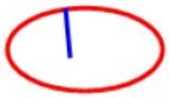
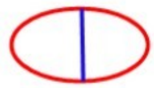
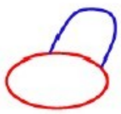
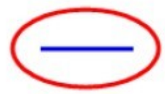
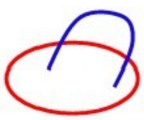
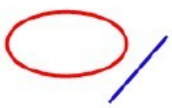
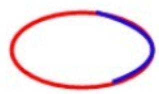
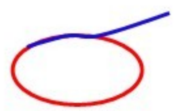
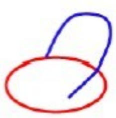
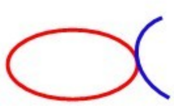
After filling in the questionnaire click on the "Submit by Email" button at the bottom right corner of the last page, a window will pop up to select the Email client, please choose/click "Internet Email" and confirm with "OK". Next, you will be directed to save an automatically generated questionnaire_QN01E.xml file. Choose a destination and then save. Later attach this file to the email and send it to Andrew a(ferdinands2000@gmail.com). If the submit by Email button does not work use the "Save As" function in the "File" menu.

Thank you very much for taking your valuable time to participate in this research.

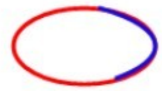
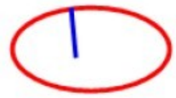
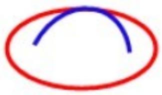
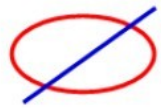
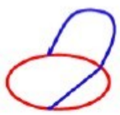
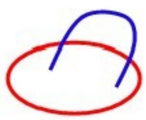
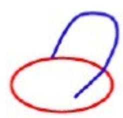
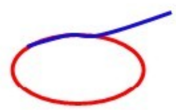
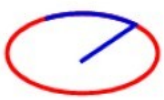
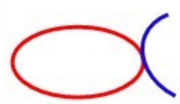
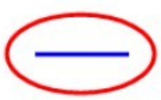
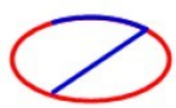
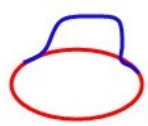
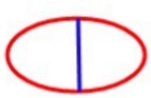
1. The geometries of **A** must be contained within the geometries of **B**.

(1) 	☐ applicable ☐ not applicable	(2) 	☐ applicable ☐ not applicable
(3) 	☐ applicable ☐ not applicable	(4) 	☐ applicable ☐ not applicable
(5) 	☐ applicable ☐ not applicable	(6) 	☐ applicable ☐ not applicable
(7) 	☐ applicable ☐ not applicable	(8) 	☐ applicable ☐ not applicable
(9) 	☐ applicable ☐ not applicable	(10) 	☐ applicable ☐ not applicable
(11) 	☐ applicable ☐ not applicable	(12) 	☐ applicable ☐ not applicable
(13) 	☐ applicable ☐ not applicable	(14) 	☐ applicable ☐ not applicable
(15) 	☐ applicable ☐ not applicable	(16) 	☐ applicable ☐ not applicable
(17) 	☐ applicable ☐ not applicable	(18) 	☐ applicable ☐ not applicable
(19) 	☐ applicable ☐ not applicable		

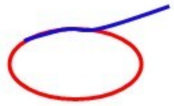
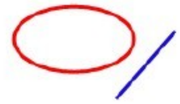
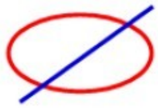
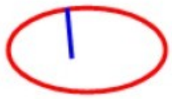
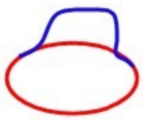
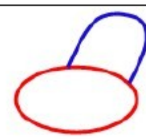
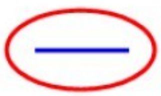
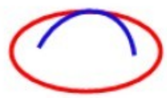
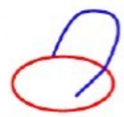
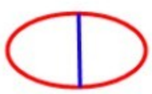
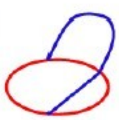
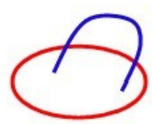
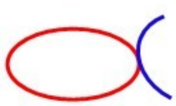
2. The geometries of **A** must be covered by the geometries of **B**.

(1)  ☐ applicable ☐ not applicable	(2)  ☐ applicable ☐ not applicable
(3)  ☐ applicable ☐ not applicable	(4)  ☐ applicable ☐ not applicable
(5)  ☐ applicable ☐ not applicable	(6)  ☐ applicable ☐ not applicable
(7)  ☐ applicable ☐ not applicable	(8)  ☐ applicable ☐ not applicable
(9)  ☐ applicable ☐ not applicable	(10)  ☐ applicable ☐ not applicable
(11)  ☐ applicable ☐ not applicable	(12)  ☐ applicable ☐ not applicable
(13)  ☐ applicable ☐ not applicable	(14)  ☐ applicable ☐ not applicable
(15)  ☐ applicable ☐ not applicable	(16)  ☐ applicable ☐ not applicable
(17)  ☐ applicable ☐ not applicable	(18)  ☐ applicable ☐ not applicable
(19)  ☐ applicable ☐ not applicable	

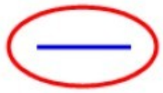
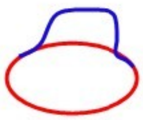
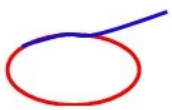
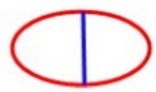
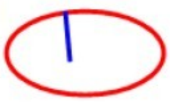
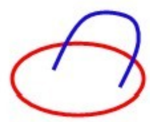
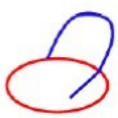
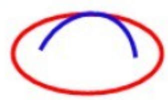
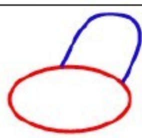
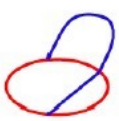
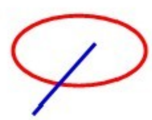
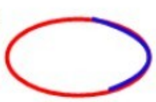
3. Each geometry in **A** must have an equivalent geometry in **B**.

(1)  ☐ applicable ☐ not applicable	(2)  ☐ applicable ☐ not applicable
(3)  ☐ applicable ☐ not applicable	(4)  ☐ applicable ☐ not applicable
(5)  ☐ applicable ☐ not applicable	(6)  ☐ applicable ☐ not applicable
(7)  ☐ applicable ☐ not applicable	(8)  ☐ applicable ☐ not applicable
(9)  ☐ applicable ☐ not applicable	(10)  ☐ applicable ☐ no applicable
(11)  ☐ applicable ☐ not applicable	(12)  ☐ applicable ☐ not applicable
(13)  ☐ applicable ☐ not applicable	(14)  ☐ applicable ☐ not applicable
(15)  ☐ applicable ☐ not applicable	(16)  ☐ applicable ☐ not applicable
(17)  ☐ applicable ☐ not applicable	(18)  ☐ applicable ☐ not applicable
(19)  ☐ applicable ☐ not applicable	

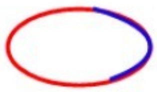
4. Each geometry of **A** must contain a geometry of **B**.

(1)  ☐ applicable ☐ not applicable	(2)  ☐ applicable ☐ not applicable
(3)  ☐ applicable ☐ not applicable	(4)  ☐ applicable ☐ not applicable
(5)  ☐ applicable ☐ not applicable	(6)  ☐ applicable ☐ not applicable
(7)  ☐ applicable ☐ not applicable	(8)  ☐ applicable ☐ not applicable
(9)  ☐ applicable ☐ not applicable	(10)  ☐ applicable ☐ not applicable
(11)  ☐ applicable ☐ not applicable	(12)  ☐ applicable ☐ not applicable
(13)  ☐ applicable ☐ not applicable	(14)  ☐ applicable ☐ not applicable
(15)  ☐ applicable ☐ not applicable	(16)  ☐ applicable ☐ not applicable
(17)  ☐ applicable ☐ not applicable	(18)  ☐ applicable ☐ not applicable
(19)  ☐ applicable ☐ not applicable	

5. Each geometry of **A** must cover a geometry of **B**.

(1)  ☐ applicable ☐ not applicable	(2)  ☐ applicable ☐ not applicable
(3)  ☐ applicable ☐ not applicable	(4)  ☐ applicable ☐ not applicable
(5)  ☐ applicable ☐ not applicable	(6)  ☐ applicable ☐ not applicable
(7)  ☐ applicable ☐ not applicable	(8)  ☐ applicable ☐ not applicable
(9)  ☐ applicable ☐ not applicable	(10)  ☐ applicable ☐ not applicable
(11)  ☐ applicable ☐ not applicable	(12)  ☐ applicable ☐ not applicable
(13)  ☐ applicable ☐ not applicable	(14)  ☐ applicable ☐ not applicable
(15)  ☐ applicable ☐ not applicable	(16)  ☐ applicable ☐ not applicable
(17)  ☐ applicable ☐ not applicable	(18)  ☐ applicable ☐ not applicable
(19)  ☐ applicable ☐ not applicable	

6. Each geometry of **A** must intersect a geometry of **B**.

(1)

☐ applicable
☐ not applicable

(2)

☐ applicable
☐ not applicable

(3)

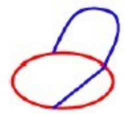
☐ applicable
☐ not applicable

(4)

☐ applicable
☐ not applicable

(5)

☐ applicable
☐ not applicable

(6)

☐ applicable
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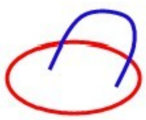
(7)

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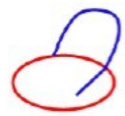
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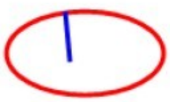
☐ not applicable

(9)

☐ applicable
☐ not applicable

(10)

☐ applicable
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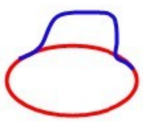
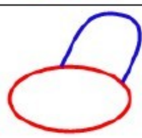
(11)

☐ applicable
☐ not applicable

(12)

☐ applicable
☐ not applicable

(13)

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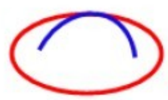
(14)

☐ applicable
☐ not applicable

(15)

☐ applicable
☐ not applicable

(16)

☐ applicable
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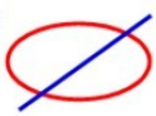
(17)

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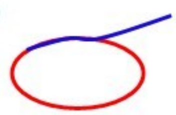
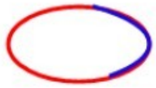
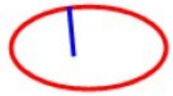
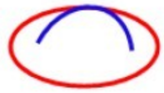
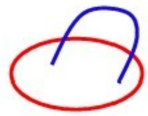
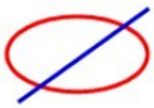
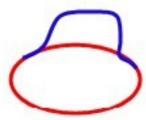
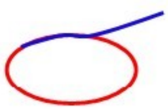
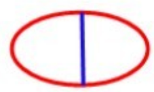
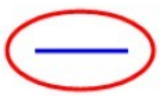
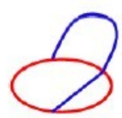
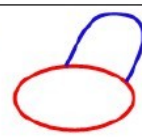
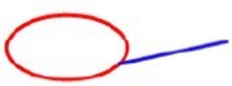
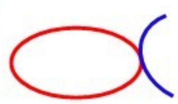
(18)

☐ applicable
☐ not applicable

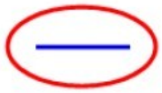
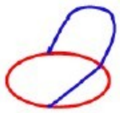
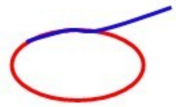
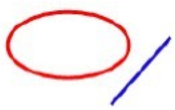
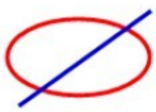
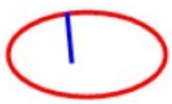
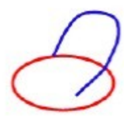
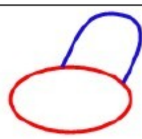
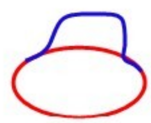
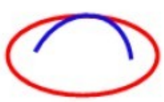
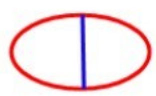
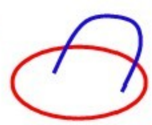
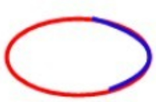
(19)

☐ applicable
☐ not applicable

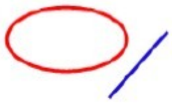
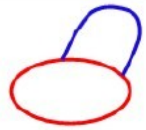
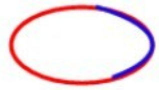
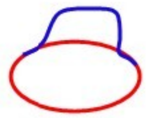
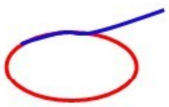
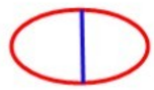
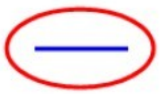
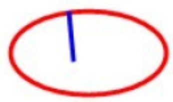
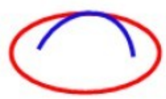
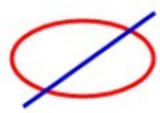
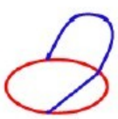
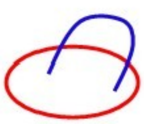
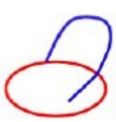
7. The geometries of **A** and **B** must be disjoint.

(1)  ☐ applicable ☐ not applicable	(2)  ☐ applicable ☐ not applicable
(3)  ☐ applicable ☐ not applicable	(4)  ☐ applicable ☐ not applicable
(5)  ☐ applicable ☐ not applicable	(6)  ☐ applicable ☐ not applicable
(7)  ☐ applicable ☐ not applicable	(8)  ☐ applicable ☐ not applicable
(9)  ☐ applicable ☐ not applicable	(10)  ☐ applicable ☐ not applicable
(11)  ☐ applicable ☐ not applicable	(12)  ☐ applicable ☐ not applicable
(13)  ☐ applicable ☐ not applicable	(14)  ☐ applicable ☐ not applicable
(15)  ☐ applicable ☐ not applicable	(16)  ☐ applicable ☐ not applicable
(17)  ☐ applicable ☐ not applicable	(18)  ☐ applicable ☐ not applicable
(19)  ☐ applicable ☐ not applicable	

8. All geometries of **A** must touch one geometry of **B**.

(1)  ☐ applicable ☐ not applicable	(2)  ☐ applicable ☐ not applicable
(3)  ☐ applicable ☐ not applicable	(4)  ☐ applicable ☐ not applicable
(5)  ☐ applicable ☐ not applicable	(6)  ☐ applicable ☐ not applicable
(7)  ☐ applicable ☐ not applicable	(8)  ☐ applicable ☐ not applicable
(9)  ☐ applicable ☐ not applicable	(10)  ☐ applicable ☐ not applicable
(11)  ☐ applicable ☐ not applicable	(12)  ☐ applicable ☐ not applicable
(13)  ☐ applicable ☐ not applicable	(14)  ☐ applicable ☐ not applicable
(15)  ☐ applicable ☐ not applicable	(16)  ☐ applicable ☐ not applicable
(17)  ☐ applicable ☐ not applicable	(18)  ☐ applicable ☐ not applicable
(19)  ☐ applicable ☐ not applicable	

9. Each geometry of **A** must be covered by one or more geometries of **B**.

(1)  ☐ applicable ☐ not applicable	(2)  ☐ applicable ☐ not applicable
(3)  ☐ applicable ☐ not applicable	(4)  ☐ applicable ☐ not applicable
(5)  ☐ applicable ☐ not applicable	(6)  ☐ applicable ☐ not applicable
(7)  ☐ applicable ☐ not applicable	(8)  ☐ applicable ☐ not applicable
(9)  ☐ applicable ☐ not applicable	(10)  ☐ applicable ☐ not applicable
(11)  ☐ applicable ☐ not applicable	(12)  ☐ applicable ☐ not applicable
(13)  ☐ applicable ☐ not applicable	(14)  ☐ applicable ☐ no t applicable
(15)  ☐ applicable ☐ not applicable	(16)  ☐ applicable ☐ not applicable
(17)  ☐ applicable ☐ not applicable	(18)  ☐ applicable ☐ not applicable
(19)  ☐ applicable ☐ not applicable	Submit by Email