A GEOSPATIAL WEB APPLICATION (GEOWAPP) FOR SUPPORTING COURSE LABORATORY PRACTICES IN SURVEYING ENGINEERING

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PREFACE

This technical report is a reproduction of a thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Engineering in the Department of Geodesy and Geomatics Engineering, September 2015. The research was supervised by Dr. Emmanuel Stefanakis and Dr. Robert Kingdon, and funding was provided by the University of Costa Rica.

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ABSTRACT

Although most of the university courses are somehow supported by a Learning management system (e.g Desire2Learn), field practices in survey engineering are not interactively supported by these systems. Also, the internet is available in almost every place today, and there are a wide range of internet services on the web. By combining these advantages with e-learning, survey practicums can be enhanced with a web-based application. The survey practicums are very specialized with precise traditional techniques used for checking measurements in the field. Thus, the combination of E-learning and practicums is not straight forward. In order to achieve this combination, there is a need to define a framework of survey exercises and a way of effectively delivering the information to the student making the process more efficient. Different outlines of surveying courses were studied in order to provide a set of exercises that can be supported by a GEOWAPP (Geospatial Web Application). This thesis proposes a combination of processing tools, created in Python, JavaScript and PHP, and Google Maps. The main objectives is to enhance the experiences that students have in the field as well as evaluating their techniques for surveying. Accuracy was chosen as the pillar of this application, which helps to gather information about students technique and computations, and to locate students' mistakes easily. This specific application is intended for self-reviewing. A prototype of the application was developed, which contains five (5) operational tools. These tools were tested with artificial and real data; this testing gave a good insight of such an application requirements. User reviews were carried out showing that students embrace the idea of similar applications. Finally, GEOWAPP showed some learning enhancing characteristics.

However, a test with a real course remains to be carried out to determine whether it is beneficial to students.

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Chapter 1. Introduction

1.1 Introduction

The accelerated development of technologies is clearly affecting our behavior today. For example, social media, like Facebook and Twitter, is affecting the way people interact and share information with each other. When there is a need for group interaction, this is filled through a social group or blog on the Internet. Many companies like ESRI and Matlab are aware of this situation, and they create institutional forums where people can place their specific questions and receive help. Also, the market is evolving into a web services based approach; companies are trying to offer services instead of program installed on personal computers. Examples of these services are AutoCAD 360, ArcGIS Online, and the new products of the Google family, using a thin client based approach. However, not only technologies and social behavior are changing into an integrated web community, but also education. More interactive ways of teaching are demanded. For instance, Stanford University offers MOOCs (Massive Online Open Courses), and there are online academies (ex. Khan Academy) that offer training in certain areas like English, accounting, database management, web development, and others.

Nevertheless, when practical field courses are taught, it is not clear how web based technologies can be applied. The practical training is especially essential in the field, where surveying operations are carried out, and is usually taught with a face-to-face approach. Although this field training is usually well taught by engineering schools, the web based teaching approach cannot be ignored. Then, some questions emerge from this situation. For example, how can we merge pure practical training in the field with a training based web application? What can be evaluated in this application? How will there the interaction be between the instructors and the students? And so on. Thus, the implementation of a web training based application is not straightforward. Therefore, there is a need for research in this area to develop a framework that can be useful for the new generation of surveyors, and that applies a web based approach.

1.2 State of the art

E-learning is an educational approach that is delivered through a computer. There are different meanings of this term depending on the sector. For example, in Business and Higher-Education, e-learning just refers to on-line activities, while in the school sector it contains both software-based and online-based learning (Campbell, 2004 as cited by Nicholson, 2007). This computer-based learning approach is sometimes called “new” however it has been around for more than 40 years (Harasim, 2006; Nicholson, 2007). Harasim (2006) provides a very detailed history of e-learning and also a taxonomy of this approach. This author divided e-learning in 3 mode categories; the adjunct mode is used to supplement a traditional face-to-face classroom; the mixed (blended) mode, in which on-line activities composes a significant part of the course curriculum and grade; and totally online mode, which is delivered completely through the web. However, the e-learning term can also refers to CALs (Computer Aided Learning), which can be offline software

(Commission 2- Professional Education, FIG, 2010; Harasim, 2006; Nicholson, 2007). M-learning is another approach where the letter "m" stands for mobile. This approach refers to learning supported by a mobile technology such as iPhones, palm tops or netbooks (Soon, 2011). Nevertheless, this concept can also be considered as E-learning depending on the definition used. E-learning sometimes generates doubts about its effectiveness among students and teachers. However, this was clarified by a publication of the U.S. Department of Education, in which it was shown that combining on-line and face-to-face elements had significant advantages over using both approaches separately (Means, Toyama, Murphy, Bakia, & Jones, 2010). Nevertheless, combining these approaches in a field practical course, such as a surveyor's field course, is not straight forward.

This problem has been addressed using CAL (Computed Aided Learning). CAL has been applied to train surveyors since the 90's. For example, the University of Nottingham has applied simulation programs; the SurCAL program was used to teach how to level a Wild T1 theodolite while AshCAL and TrimCAL programs were used to teach how to use Ashtech and Trimble GPS receivers respectively. These programs are not used anymore because they are out-of-date. However, NEST (Nottingham Engineering Surveying Teaching) was deployed in 2009. This application combines the benefits of the simulation programs and the web based e-learning (Roberts & Gray, 2010). Additionally, the Department of Spatial Science of Curtin University has tested an "online simulation for levelling" tool, which has shown its usefulness in developing the students' levelling skills (El-Mowafy, Kuhn, & Snow, 2013). Although these tools are interactive and effective, they can be enhanced by providing a more interactive framework using geospatial web applications.

The geospatial web is a relatively new technology built on the Web 2.0, which allows more interaction. Also, the geospatial web through its interaction provides a spatial framework for students to learn geographical concepts (Harris, Rouse, & Bergeron, 2010). Harris et al. (2010) refer to the geospatial web as a tool for complementing geographical concepts without using thick-client GIS applications. HydroViz is a web-based application designed for improving the hydrology education using Google Earth. With this application, the students have the opportunity to apply and model theoretical concepts of hydrology. The students' opinion of HydroViz was favorable in a study published in 2012. In this study, the students were likely to think that HidroViz improves on current teaching tools/methods (Habib, Ma, Williams, Sharif, & Hossain, 2012). This application is a good example of enhanced learning through the spatial web. However, this is a classroom-based application. If surveying engineering field practices are to be supported, another kind of application must be developed; which students can access even if they are in the field.

1.3 Definitions of the Research Questions / Hypothesis

1.3.1 Hypothesis

Teaching a survey lab practice can be enhanced by utilizing a geospatial web application tool (GEOWAPP). This tool provides a framework for supporting some field practices and can be used on the field. Furthermore, this tool must be extensible in order to provide room for future development.

1.3.2 Research Questions.

This research is defined by the following research questions.

- How can the survey practicum be supported by the GEOWAPP inheriting some of the advantages of the geospatial-web? (Practices)
- Which field practices should be included, and how these can be supported and managed in this web-based application? (web application design)
- How can the students access the application to self-evaluate their measurement? (Interface application)
- Which combination of technologies would be suitable to develop this application?

1.3.3 Research objectives (RO)

1. Design a GEOWAPP that can be able to support survey field practices.
2. Determine the exercises that will be supported by the application: this task implies to review of the practicum syllabi in order to make the application compatible with what is already being taught.
3. Design different ways and processing tools for supporting the exercises taking into account both the input and output information.
4. Develop a prototype of the GEOWAPP. This tasks implies to choose different technologies, programing languages, and an API (Application Programing interface. e.g. Google Maps)
5. Test the functionality of the web application tool: the functionality of the GEOWAPP will be tested, and the strong and weak characteristics of the application will be pointed out.
6. Gather students' evaluation of the prototype.

Chapter 2. Application Design

1.1 Modeling

The fourth principle of modelling is that “No single model is sufficient. Every nontrivial system is best approached through small set of nearly independent models” (Booch, Rumbaugh, & Jacobson, 1999). Thus, modelling is the most important task in this research. In this chapter, the GEOWAPP application will be designed taking into account the different theories behind its development. First, the global architecture of the GEOWAPP will be addressed in order to have a better understanding of the interaction between the individual components. This part of the project will be modelled with UML diagrams. Then, the survey practices will be analyzed in order to make GEOWAPP compliant with these courses. As a consequence of this analysis, an exercise schema will be created. The exercise schema will lead to design of a set of analytical tools, which will aid students in their survey practices. Next, the methods and tool for accuracy testing will be discussed in section 2.3 and 2.4. Finally. The database design and the authoring are addressed in section 2.5 and 2.6.

1.1.1 Global Architecture

The global architecture of a GEOWAPP is defined with three diagrams: a use case diagram, a component diagram, and an activity diagram.

Figure 2.1 shows the use case diagram, describing the interaction of instructors and students with the GEOWAPP interface. The students will be able to retrieve examples, compare their observations, and visualize contextual information. The instructors will be able to post examples and exercises, retrieve the same information as students, and visualize more information in reports.

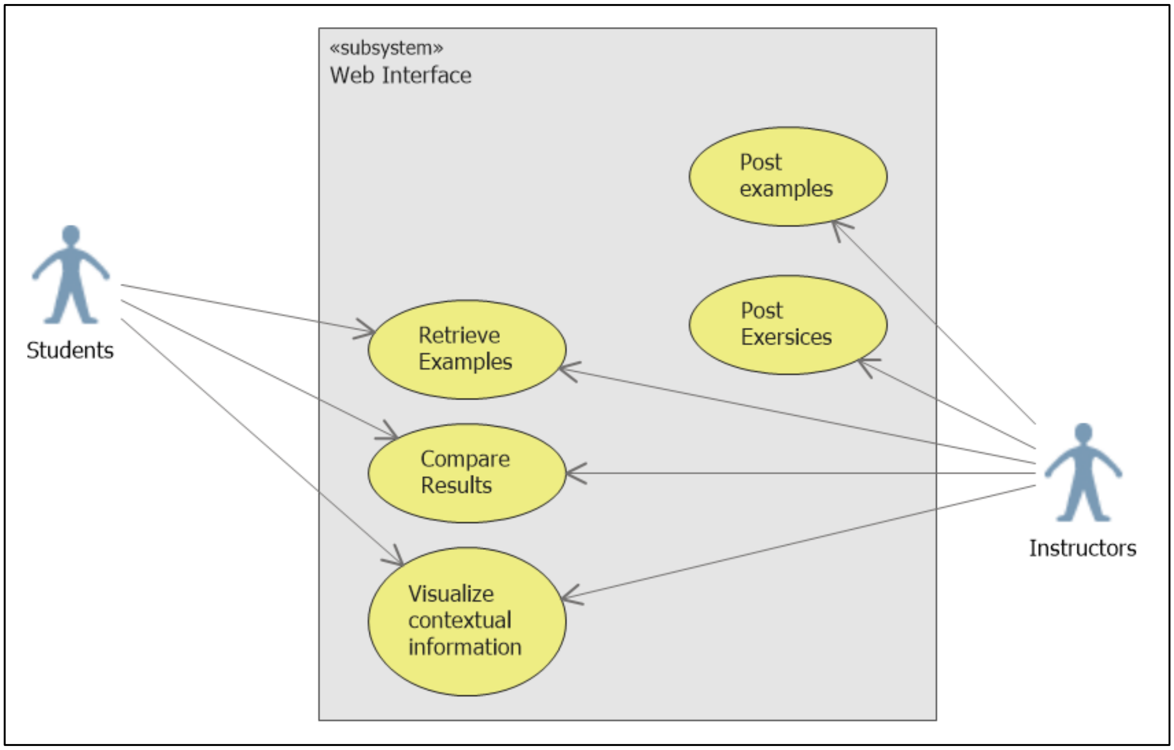


Figure 0.1: The yellow ellipses show the services that will be provided to the students and the instructors.

Figure 2.2 shows a component diagram, describing the different parts of the application. As shown, the application is composed of the web interface, the service provider, the DBMS, the database, the catalog document, and some APIs from google services.

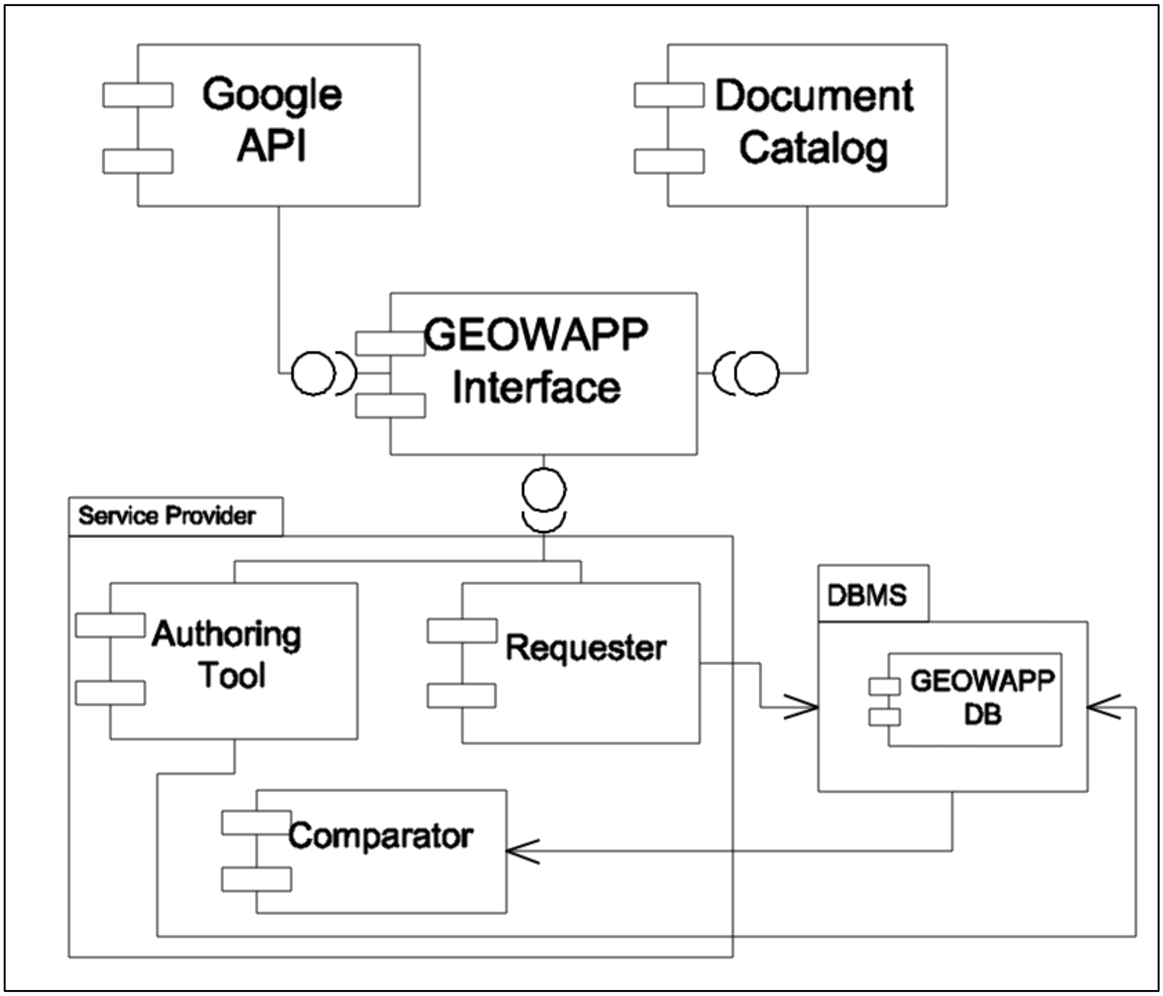


Figure 0.2: This UML component diagram describes the GEOWAPP.

The service provider will be composed of three components: the requester, the comparator, and the authoring tool. The requester will post the required information to the DBMS system, which will retrieve data stored in the database or in text files. If a student merely wants to see a layer, the GEOWAPP will display it on the interface. However, if the student wants to compare his/her observations, this data will be sent to the comparator tool. This tool will be able to compare stored data (samples) with the observed data, producing an output that will inform to students about the accuracy of their observations. This output will depend on the practical exercise that was assigned. In addition, the authoring tool will provide instructors the ability to import new data into the database, such as control points, bench marks, topographical features, and others.

The interface will provide a link to a document catalog, where instructors can provide examples of static maps (maps in PDF, JPG, etc.), field notes, and other static documents. Figure 2.3 shows the activity diagram of the GEOWAPP. By combining the three diagrams the reader will have a better notion of the GEOWAPP.

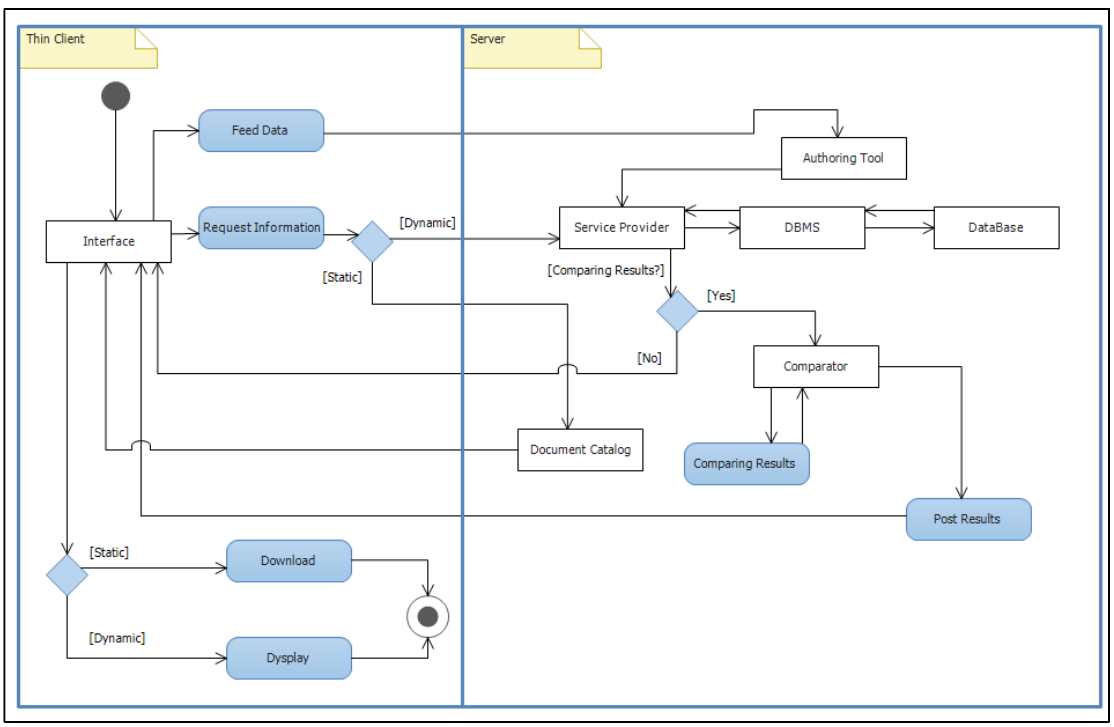


Figure 0.3 This activity diagram shows the different actions that will be carried out by GEOWAPP.

1.2 Exercises' schemata

Sepehr (2009) states that the type of data as the reason for storing it in a geodatabase must be specified before selecting any approach for implementing the geodatabase. In this application, the field exercises will limit the data types. Therefore, these exercises must be designed before either the database or any other component of the GEOWAPP.

Before designing the prototype exercises, the practicum courses must be studied. These courses consist of GGE 1001(Introduction to Geodesy & Geomatics), GGE 1803 (Practicum for Civil Engineers), and GGE 2013 (Advance Survey Practicum).

1.2.1 Review of GGE's field practices exercises

The outlines and labs of the GGE's practicums have been reviewed in order to adapt the GEOWAPP to what is already being taught. This review was organized by course. For each course, a short description was written about which exercises could be included in the GEOWAPP, and how the accuracies could be tested by a GEOWAPP.

1.2.1.1 GGE 1001 Introduction to Geodesy and Geomatics

This an introductory course for first-year students, coordinated by Dr. Peter Dare. Several other GGE professors are also involved: Dr. Emmanuel Stefanakis, Dr. Marcelo Santos, Dr. Yun Zhang, and Dr. John Hughes Clarke. Although this course is not a practical course per se, it has 3 lab exercises (Dare, 2013a; Dare, 2013b; Dare, 2013c) which can benefit from a GEOWAPP. The lab descriptions are:

- Lab 1. Height Difference by Differential Leveling: in this lab, the students are required to determine elevations using differential leveling. This elevations can be provided by a GEOWAPP, as well as the misclosure of the loop. Then, students can test their results in the GEOWAPP and check the accuracy of their measurements.

- Lab 2. Traversing Exercise: in this lab, students must carry out a traversing exercise, to calculate the coordinates of a point. The GEOWAPP can be applied in a similar way as for the differential leveling exercise.

- Lab 3: Topographic survey: in this lab, students are asked to survey topographic features (TFs) in front of the Old Arts Building. Important topographic feature (TF) locations can be stored in the GEOWAPP database. Then, the students can compare their results with the known topographic features (KTFs). In this way, the students will be notified about any missing TF. Also, the quality of the survey can be assessed. However, there is a need for programing an application that can compare between the student features and the reference features.

1.2.1.2 GGE 1803 Practicum for Civil Engineers

This is a two week long course where the students develop their professional skill in field surveying. The course is taught by Ryan White (Surveying) and Dave Fraser (GIS) (White & Fraser, 2013). The GEOWAPP can assist with:

- Traverse survey: after students have done the traverse exercise they can check their accuracy in the GEOWAPP. The GEOWAPP can adjust the traverse using the "Bowditch Rule". Then, the students can check their results with the calculated results made by the GEOWAPP.

- Differential leveling: If a differential levelling network is done, the application would apply network adjustments and the student would be able to compare their result with the computed results of the GEOWAPP.

- Topographic survey/map: A reference TIN can be stored in the database. Then, when the students generates their own TIN the difference between both of them can be reported. This report can have some advice and also can show where points are needed or which place is over surveyed, depending on the accuracy needed. However, there is a need to program an application that can compare between the two TINs. Moreover, examples of topographic maps and of corresponding field notes can be provided. Also, there is another method that can be used to test the students' observed ground points (SOGP). This method consists of using the student's observations for interpolating the z coordinate of the known points. Then, the differences between the interpolated z coordinates and the known z coordinates will give an indicator of the observation accuracy.

1.2.1.3 GGE 2013 Advanced Surveying Practicum.

Like the course GGE 1803, GGE 2013 is a two week long course. GGE 2013 is coordinated by Dr. Dare and the Ph. D. student, Gozde Akay (Dare & Akay, 2014). This course is more advanced than the previous two courses. However, the course can still be assisted as described

- Control network: The students are required to densify a local control network within the work area using GPS. This densification must be carried out using coordinates in the NAD83 (CSRS) system. This exercise can be supported by adding control station coordinates to the GEOWAPP. Then, if there is a problem during post processing or if the coordinates' epoch is not correct, the application can show students differences between the coordinates and advice on how to fix the problem. This Control network requires also a survey of a traverse.

- Topographic survey: Using the coordinate densification mentioned before, students are asked to carry out a topographic survey of an indicated area using a specified coding scheme. This exercise can be supported in two ways.

    1. The method proposed for Lab 3 in GGE 1001 can be applied.

2. The TIN can be compared using the method proposed for the course GGE 1803.

- Heighting: The students are asked to determine heights of all the points using GPS and/or differential leveling and/or vertical angle measurement to local height benchmark. By programing an application tool, it would be possible to measure the accuracy of the topographic network. For example, the least squares method can be applied to a network, with redundant measurements. The application can ask for 3 quantities: the distance between points, the vertical differences, and the students' computed values. Then, the application will report back the differences between the students' computed values and the GEOWAPP results.

- Topographic plan: The students are asked to produce a topographic plan of the area surveyed. The web mapping tool can provide links to good examples of topographic maps done in the past, in order to guide students about which map elements the map should contain.

In summary, the practicum exercises that will be supported by the GEOWAPP are listed in table 2.1.

Table 0.1 Exercises classes classified by course

Exercises	GEE 1001	GGE 1803	GGE 2013
Traversing	*X*	*X*	*X*
Differential Leveling	*X*	*X*	*X*
Topographic Survey	*X*	*X*	*X*
Network densification			*X*
Topographic plan	*X*	*X*	*X*

1.2.1.4 Required Data

Table 2.2 shows the data required by each exercise to be implemented in the GEOWAPP.

Table 0.2: Exercises classes classified by course

Exercises	Data
Traversing	Control points coordinates
Differential Leveling	Benchmark heights
Topographic Survey	Control points coordinates, TF with code, DTM (digital Terrain Model), or KTF coordinates.
Network densification	Coordinates of the control points
Topographic plan	Map examples, map check-list
Examples	Map examples, field notes examples, link to external sources, etc

1.3 How to Test Accuracies

One of the concerns of this research is to provide appropriate reports to students. Then, instead of giving the signed differences, the GEOWAPP can retrieve an absolute value of the differences. This approach is helpful in traversing exercises, differential leveling exercises, and in the network densification. However, the topographic survey exercises have different requirements.

A topographic plan is composed of representations of TFs and of relief. Thus, for testing the accuracy of a topographic plan two different tools are required. As briefly mentioned in Section 2.2, the vertical accuracies of the observations can be compared with a TIN or with the interpolation computation previously discussed. Since summation of the differences between the interpolated values in the TIN and the observations should tend to 0 if the observations are correct, some statistical tests can be applied in order to test the accuracy of the vertical observations. This computation will be addressed in more detailed in section 2.4 (*vertical comparator*). In the previous subsection, a spatial proximity tool was mentioned, which will be able to compare the students' observed topographic features (SOTF) coordinates with the KTF coordinates, which are stored in the application. Also, this will be addressed in section 2.4 (Proximity Comparator).

1.4 Required tools for testing accuracies

1.4.1 Traversing comparator

This tool will provide support to students in the field. After observing the traverse, students can do a quick calculation in the field to provide the distance and azimuth. Then, the GEOWAPP can adjust the traverse with the “Bowditch Rule” (also known as the Compass Rule) and calculate the misclosure residuals for students’ observations. Thus, the students will know if they need to repeat their work.

The formulas for the Bowditch Rule, linear misclosure, and relative precision are described as follows (Wolf & Ghilani ,2006):

$$\textit{Correction in departures for AB} = -\frac{\textit{Total departure misclosure}}{\textit{Traverse perimeter}} x\textit{Length of AB}) \quad \textbf{Eq. 0.1}$$

$$\textit{Correction in latitudes for AB} = -\frac{\textit{Total latitude misclosure}}{\textit{Traverse perimeter}} x\textit{Length of AB} \quad \textbf{Eq. 0.2}$$

$$\textit{Linear misclosure} = \sqrt{(\textit{Departure misclosure})^2 + (\textit{Latitude misclosure})^2} \quad \textbf{Eq. 0.3}$$

$$\textit{Relative Precision} = -\frac{\textit{Linear Misclosure}}{\textit{Traverse length}} \quad \textbf{Eq. 0.4}$$

For implementing this service, the information needed is <Azimuth and Distance> or <Bearing and distance>. Two possible scenarios can be supported: first, a field crew might traverse from one known point to another known point, both of which are stored in the database. Second, a work team might start from an unknown point and perform a loop traverse back to the same point.

The departures and the latitudes, which are the X and Y projections of the polar coordinates of a vector are computed according to Eq. 2.5 and 2.6.

$$\boldsymbol{Departure = Length\ of\ AB * sin\ (Azimuth\ from\ A - B)} \qquad \textbf{Eq. 0.5}$$

$$\boldsymbol{Latitude = Length\ of\ AB * cos(Azimuth\ from\ A - B)} \qquad \textbf{Eq. 0.6}$$

(Wolf & Ghilani, 2006)

While the students are in the field, the most important information is the linear misclosure, the residuals of latitude and departure, and the relative precision. However, the full Bowditch rule report, shown in Table 3, can be used by the instructors to mark the assignment.

An example of the schema of the students' output is shown in Figure 2.4, using the XML language.

<residual of departure> 15 cm </ residual of departure >

<residual of latitude>7 cm</ residual of latitude >

<linear misclosure> 16.553 cm</ linear misclosure>

<traverse length>120 m</traverse length >

<relative precision>1 / 724.9485 < /relative precision >

<message>the traverse is off-tolerance</message >

Figure 0.4: This figure shows an example of the schema, which contains useful information for students

Table 0.3: Proposed format of the Bowditch rule report

Station	**Preliminary Azimuths**	**Length (m)**	**Unadjusted Departure**	**Latitude**	**Balanced Departure**	**Latitude**	**Coordinates Eating**	**Nothing**
A							XX	XX
	XXX	XXX	XX	XX	XX	XX		
B							XX	XX
	XXX	XXX	XX	XX	XX	XX		
A							XX	XX
Sum			XX	XX	0	0		

This format is taken from Wolf and Ghilani (2006). A full description of the Bowditch rule is also given in their book. In addition, Milne (1984) shows a set of routines for computing a traverse, which include the Bowditch adjustment (Compass Rule). These routines were programmed in BASIC (Milne, 1984).

1.4.2 Leveling Tools

Differential leveling is a very precise method for determining the height differences between objects. This methodology is found in a most surveying textbooks (e.g.

Wolf and Ghilani (2006), Kavangh (2009)). Figure 2.5 shows the main concepts of differential leveling.

As indicated, the measurements begin at a point A, with known elevation; and finish at an unknown point B. The Height Differences (H.D.) are determined by subtracting the Foresight (F.S.) reading from the Backsight (B.S.) reading. For calculating the final elevation, this HD is added to the Initial Elevation. In order to determine the elevation of other points, this process must be repeated until the desired points are reached. In leveling, the measurements are repeated backwards, from (B to A), in order to check the initial elevation (A).

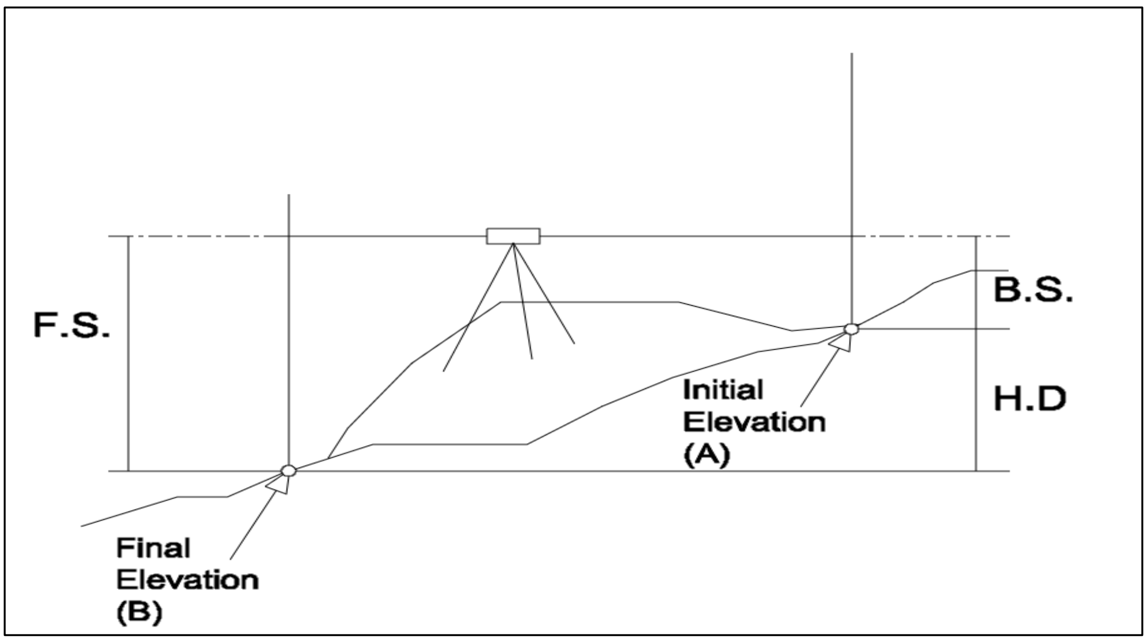


Figure 0.5: This figure shows the main concepts of differential leveling where the instrument should be always parallel to the local gravity field. B.S. and F.S. stand for Backsight and Foresight. Source: own elaboration.

In order to support this practice with the application, the GEOWAPP provides two options:

1.4.2.1 Leveling Comparator

The height difference will be known by the GEOWAPP because the control points will be stored in the database. The students can then post their measured height difference, and the tool can reply to indicate whether the measurements are within a tolerance specified by the instructor. This will be done by comparing the computed H.D. and the stored H.D. The whole computation can be carried out by the GEOWAPP, and absolute values of residuals can be shown as well as the precision. The precision of leveling is computed with the following formula.

$$\boldsymbol{C = m\sqrt{K}} \qquad \textbf{Eq. 0.7}$$

where:

C is the misclosure in mm,

m is a constant to be compared with the standard of precision, and

K is the perimeter of the leveling, which is distance between point A and B multiplied by 2, in kilometers.

Figure 2.6 shows the schema definition of the information that will be retrieved from GEOWAPP.

<misclosure> 0.030 m</misclosure>
<distance>0.300 km</distance>
<perimeter>0.600 km </perimeter>
<m>0.38730</m >
<order of accuracy>Fourth order < / order of accuracy>
<message>the accuracy is insufficient</message >

Figure 0.6 shows the students report schema for the differential leveling.

The orders of accuracy are specified in the outline of GGE 1803: Practicum for Civil Engineers, and are also shown in Table 2.4.

1.4.2.2 Leveling Least Squares Checking

For advanced surveying students, a leveling network is generated and a least squares adjustment can be performed. In this case, a measurement of the students' observation accuracy is given by the statistics of the adjustment (mean, standard deviation, and variance). This adjustment method in Wolf & Ghilani (1997), Wolf & Ghilani (2006). However, there are a huge amount of literature about the least square adjustment.

Table 0.4: Order of accuracies of a leveling network.

Order of Accuracy	Required Misclosure
Special Order	3mm x √K
First Order	4mm x √K
Second Order	8mm x √K
Third Order	24mm x √K
Fourth Order	120mm x √K

Source: White and Fraser (2014)

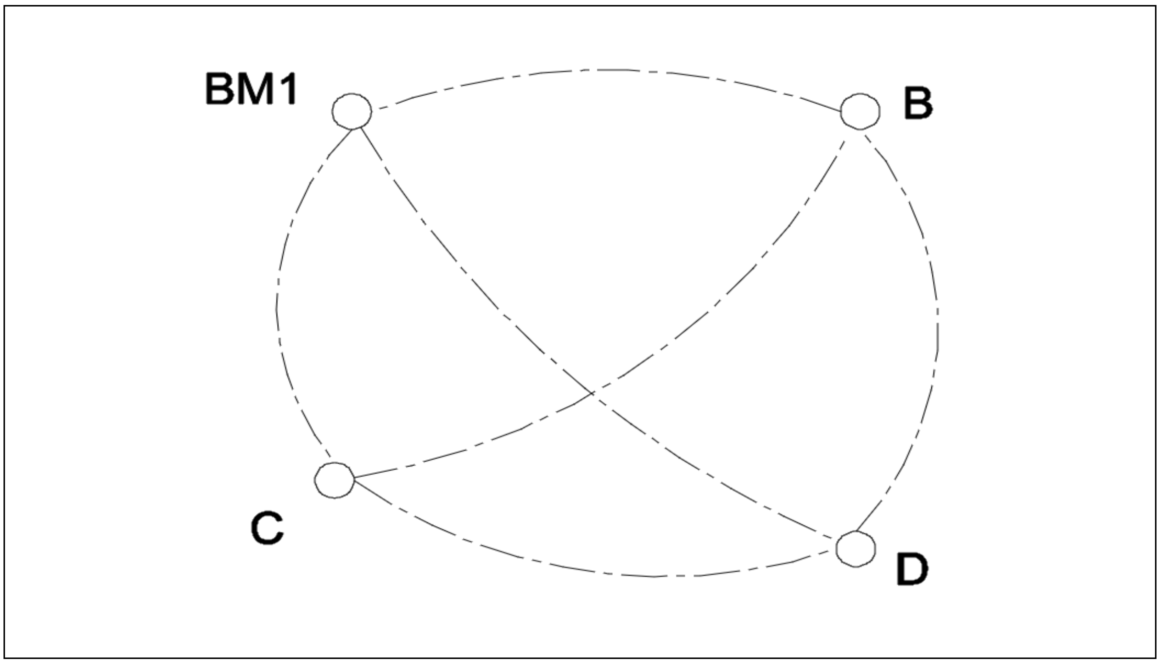


Figure 0.7: a sketch of a topographic survey is shown in which the least squares will be applied. BM1 is a known Benchmark and BCD are new benchmark that will be measured.

Figure 2.7 shows an example of a levelling network. In the network shown, there are 3 additional observations for computing each elevation: BM1-B, B-D, D-C, C-BM1, BM1-D, and B-C. Thus, a least squares adjustment can be applied. The formula for computing the final values is:

$$\boldsymbol{X} = (\boldsymbol{A^T W A})^{-1}(\boldsymbol{A^T W L}) \qquad \textbf{Eq. 0.8}$$

where:

X is the matrix of unknowns,

A is the matrix of coefficients,

L is the matrix of observations, and

W is the matrix of weights.

(Wolf & Ghilani, 2006)

The matrix of weights in leveling is usually a diagonal matrix, composed of the inverse of the distances between benchmarks.

The Residual matrix b (V) is calculated according to Eq. 2.9.

$$\boldsymbol{V = AX - L} \qquad \textbf{Eq. 0.9}$$

(Wolf & Ghilani, 2006)

In addition, the standard deviation is computed according to Eq. 2.10 and Eq. 2.11.

$$\boldsymbol{\sigma_0} = \sqrt{\frac{\boldsymbol{V^T W V}}{\boldsymbol{r}}} \qquad \textbf{Eq. 0.10}$$

and

$$\boldsymbol{\sigma_{x_i} = \sigma_0 \sqrt{q_{xixi}}} \qquad \textbf{Eq. 0.11}$$

where:

σ_0 is the standard deviation of unit weight,

r is the degrees of freedom,

q_{xixi} is the diagonal values of matrix $(A^T W A)^{-1}$, and

σ_{xi} is the standard deviation of the adjusted value.

(Wolf & Ghilani, 2006)

After applying this method, a report can be given to students. This report is described as follows (see Figure 2.8).

<residual 1>0.001 m </ residual 1>

…

<residual n>0.003 m </ residual n>

<distance 1>0.300 km</distance 1>

…

<distance n>0.200 km</distance n>

<elevation 1>10000.000m </elevation 1>

<st. dv. 1>0.002 m</ st. dv. 1>

…

<elevation n>10099.531m </elevation n>

<st. dv. n>0.004 m</ st. dv. n>

<message>the accuracy is enough</message >

Figure 0.8: this figure shows the schema definition of the students report using the Leveling Least Squares Checking tool.

1.4.3 Network comparator

All possible control points must be stored in the database in order to allow students to check their accuracy. Each point must have coordinates, and the precision of the coordinates. In this way, if a post-processing fails, students' accuracy can be assessed to determine whether they need to repeat the process or not. Moreover, this tool must be able to give them some advice on what would be the common mistakes. The schema definition for the report is shown in Figure 2.9

<station x>
<linear difference>0.010 m </linear difference>
<difference latitude (x) >0.005 m </ difference latitude (x) >
<difference longitude (x) >0.010 </ difference longitude (x) >
</station x>

Figure 0.9: this figure shows the schema definition of the student report for station x.

1.4.4 Topographic survey comparator

1.4.4.1 Proximity tool comparator

This tool will compare KTFs with SOTFs. For example, if a student is observing the coordinates of a tree and the same tree is already stored in the database (KTF), a comparison of the proximity between the two features will be carried out. Then, if the feature is within the tolerance, it will be accepted. If the feature is not within the tolerance, it will be marked as outlier.

The above mentioned check requires that each TF be encoded, as done by Sepher (2009). These codes are shown in Table 2.5. Tolerances for each feature, however, must be defined in this research.

In order to define the tolerances, the errors in the measurements have to be analyzed. Nickerson (1978) wrote a report about the different errors found in surveying observations. These errors can be divided into internal and external: internal errors are related with the equipment itself while external errors are related with the environment. For this application, the correction for environmental conditions, like temperature and humidity, and systematic errors are assumed to be already accounted by students. Besides, the analysis of every measurement would not be feasible for the proposed application; however, a common internal error will be derived from Nickerson's formulas.

Table 0.5: Specification of the code system for the survey practicums.

New feature coding system	Feature type	Students' feature codes
BL	*Buildings*	*· Buildings* *· BLD*
BN	*Benches*	*· Benches*
BR	*Bike racks*	*· Benches&Bikerack*
Contours	*Contour lines*	*· Contours*
CB	*Curbs*	*· Curb* *· Top of curb* *·Curbs&walkways&sidewalk*
EB	*Electrical boxes*	*· Electrical box*
FN	*Fences*	*· Fence*
GF	*Green fields*	*· Vegetation*
HD	*Hydrants*	*· Hydrant* *·Manholes&Firehydr&sign*
LI	*Lights*	*· Light*
LP	*Lamp posts*	*· Lamp Post* *Tree&Post*
MH	*Manholes*	*Manholes&Firehydr&sign*
PG	*Play grounds*	-
PL	*Parking areas*	*· Parking Lot*
SI	*Signs*	*· Sign* *· Signs*
ST	*Streets*	*· Asphalt* *· Road* *· Road&Sidewalk*
SD	*Storm drains*	*· Storm Drain*
SW	*Sidewalks or any type of walkways*	*· Sidewalk* *· Road&Sidewalk* *·Curbs&walkways&sidewalk*
WA	*Treed or wooded areas*	*· Woods* *· Tree Line*
TR	*Trees*	*· Vegetation* *· Tree* *· Tree&Post*
RW	*Retaining Walls*	*· Retaining Wall* *· RWALL*
TP	*Telephone poles*	*· Telephone poles*

Source: (Sepehr, 2009)

In angular observations, Nickerson (1978) states that there are three different internal errors (σ_i): pointing error(σ_p), reading error (σ_r), leveling error($\sigma_{L)}$ (see Eq. 2.12). These are related according to (Nickerson, 1978):

$$\boldsymbol{\sigma_i}^2 = \boldsymbol{\sigma_p}^2 + \boldsymbol{\sigma_r}^2 + \boldsymbol{\sigma_L}^2 \qquad \textbf{Eq. 0.12}$$

Table 0.6: Acceptable internal error for different classes of survey

Order of survey	Order of class	Nominal Relative accuracy	Internal Error.
1		1:100 000	0”. 33
2	1	1: 50 000	0”. 33
2	2	1:20 000	0”.47
3	1	1: 10 000	0”.69
3	2	1: 5 000	1”.39

Source: Pfeifer (1975) as cited by Nickerson (1978)

These internal errors are meant for experienced observer, who will ensure that the equipment is set up correctly. As students are learning how to measure and setting up, the internal error (σ_i) can be greater than σ_i that would be made by an experienced observer.

In addition to angular errors, the distance measuring error has to be taken into account. For mapping topographical features, EDMs (electronic distance measuring instruments) are used in the survey practicums. These instruments have built-in errors, although McCormac et al. (2013) state that “Instrument errors are usually quite small if the equipment has been carefully adjusted and calibrated”. In addition, McCormac, et al. (2013) states that the EDMs manufacturers give an instrument constant for the built-in error, which is called *instrumental error (IE)*; and another value that is dependent on the distance, called *measuring error (ME)*. McCormac, et al. (2013) compute the EDMs error using the following formula:

$$\boldsymbol{EDMs\ Error = IE + D *\ ME} \qquad \textbf{Eq. 0.13}$$

Where **D** is distance.

However, as *IE* and *ME* are random and independent errors, the EDMs Error should be computed as the square root of the two squared quantities. This operation is shown in the next equation.

$$\boldsymbol{EDMs\ Error = \sqrt{IE^2 + (D * ME)^2}} \qquad \textbf{Eq. 0.14}$$

For example, the EDMs Error given by the manufacturer look like $\sqrt{(5\ \mathrm{mm})^2\ +\ (\mathrm{D} * 10\mathrm{ppm})^2}$ or $\sqrt{(\mathrm{IE}^2 +\ D * \mathrm{ME}^2)}$. If a distance of 100m has been measured, the total error will be $\sqrt{(5\mathrm{mm})^2 + (10 * 100 * 1000/1000000)^2}$ mm or 5.10 mm.

The last error that will be taken into consideration is the specific feature error (SFE). This error will be caused by the characteristics of the topographical feature. For example, if the location of a tree needs to be observed, the SFE is the uncertainty in determining the location of the tree center. For the purposes of this project, the expertise of the instructor will be used to determine these values.

Merging the three errors together, the tolerance of TFs are define. Normally, an Elliptical Error Probable (EEP) should be defined because of the propagation of the errors. This concept is shown in Figure 2.10.

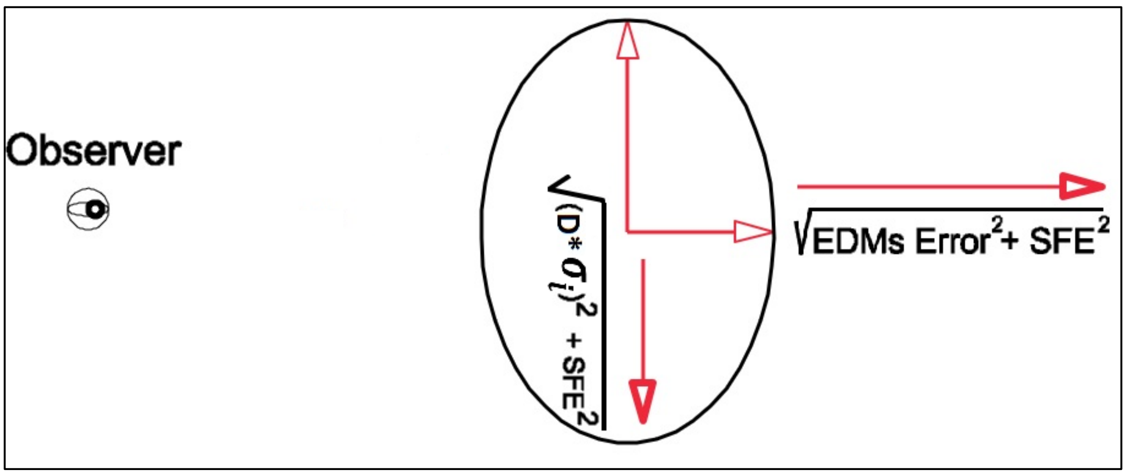


Figure 0.10: The EDMs error propagates along line of sight from the observer while σ_i (radians) propagates across the line of sight; . The SFE is added to both errors (EDMs error and σ_i).

However, because the position of the observer is hard to locate in a student's observation coordinate file, then a Circular Probable Error (CPE) can be computed instead of an EEP. The formula for computing the 50% CPE is shown next.

$$\boldsymbol{R = 0.75 * \sqrt{(EPP\ Minor\ Axis\ )^2 + (EPP\ Mayor\ Axis\ )^2}} \qquad \textbf{Eq. 0.15}$$

Source: (Mathematical Analysis and Research Corp., 1987)

The Mathematical Analysis and Research Corp. (1987) demonstrated the relationship between the confidence level of the EEP and the CPE for two extreme cases, when an EEP is circular and when an EPP is highly skewed. For example, if a CPE is derived from a 95 % EEP, this CPE confidence level will vary between the value of 93 % and 97 %.

A confidence level of 99 % is taken as standard for accepting or rejecting a measurement. Expansion factor can be derived from the Normal distribution. This expansion factor for 99% is approximately 3.035.

The 99% CPE can be derived from a 99% EEP by using Eq. 2.15 and the corresponded expansion factor. The formula is shown next.

$$\boldsymbol{R = 0.75 * 3.035 * \sqrt{[\sqrt{(D * \sigma_i{}^2 + SFE^2)}\,]^2 + [\sqrt{(EDMs\ Error^2 + SFE^2)}\,]^2}} \qquad \textbf{Eq. 0.16}$$

Then, the confidence level from this CPE vary between 99.5% and 97.3%, derived from Mathematical Analysis and Research Corp. (1987). Then, our tolerance will be defined as R. The concept of this tolerance can be represented graphically as in Figure 2.11.

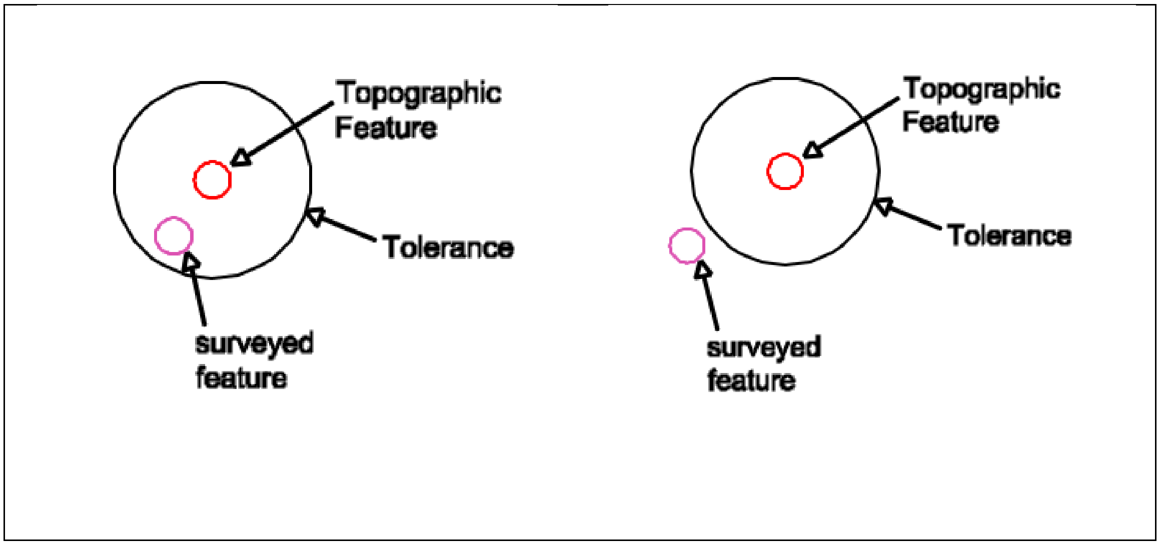


Figure 2.11-A **Figure 2.11-B**

Figure 0.11: This figure shows a comparison between the TF and the surveyed feature by students. In Figure 11-A, the TF is in tolerance while in Figure 11-B, this feature is off tolerance

An example for the tolerance determination is shown next.

Max Distance = 300 m

Survey accuracy = 3-2

Angular internal error = 1".39

Angular error in distance = sin (1".39)* 300m = 0.002 m.

EDMs Error = 5mm +10 ppm

$$= \sqrt{(5\text{ mm})^2 + [\left(300\text{m} * 10\text{ppm} * \frac{1000}{1000000}\right)\text{mm}]^2} = 5.8\text{ mm}$$

SFE = 30 mm

$$R = 3.035*0.75*\sqrt{\left(\sqrt{(5\ \mathrm{mm})^2 + (30\mathrm{mm})^2}\right)^2 + (\sqrt{(30\mathrm{mm})^2 + (5.8\mathrm{mm})^2})^2}$$

R = 98.2 mm

Tolerante = 98.2 mm

Although CEP is a suitable solution for this application, some observations that should be rejected will be accepted and some observations that should be accepted will be rejected.

The tolerance values will be included in the application database and will have a schema shown as follows.

Table 0.7 Feature tolerance value

CODE	**FEATURE_TYPE**	**TOLERANCE(M)**
BL	Buildings	0.040
…	…	…
xxx	xxxx	Xxxx

In addition to Table 2.7, the coordinates of the known topographic features (KTFs) will be needed. Thus, instructors have to submit 2 pieces of information: the table of tolerance values, and the KTF coordinates. Instructors will create these sample, which will be composed of important features in the survey area.

1.4.4.2 Vertical tool comparator

The main purpose of this tool is to determine whether the students' survey meets the requirements of the exercise. In spatial data, the only way to confirm that these requirements are met are statistical tests at moderate cost (Aguilar, Aguilar, & Aguera, 2007). Hohle and Holhe (2009) state that the accuracy of measurements in a DTM are usually based in the assumption that the errors follow a Gaussian distribution, and that no outliers exist. Often this is not true. Their research was based on DTMs derived by Photogrammetry and Remote Sensing. These authors further underline the fact that there may be some unwanted objects (Ex. cars, buildings and people), which may cause that some of the ground points to be incorrectly labeled. These unwanted objects will not be present in SOGPs, which will be generated during their exercises, because students will be able to pick their ground points (GP) and label them correctly. Such GPs, which are surveyed with total stations, have been used to measure accuracies of DEM in previous studies (Gil et al., 2013; Reutebuch et al., 2000). Because of this advantage of SOGPs, it can be assumed that their errors follow a Gaussian distribution. As result, common statistical accuracy measures can be used: σ (Standard Deviation), $RMSE$ (Root Mean Square Error), $\bar{\mu}$ (Mean Error). Furthermore, the Standard Normal Distribution and Student's t Distribution can be used for creating confidence intervals, depending whether population or sample quantities are used. These statistical measures were suggested by Holhe and Holhe (2009) when the Gaussian distribution requirement is met. Table 2.8

shows the formulas for calculating these statistical measures. On the other hand, it is possible to test the histogram of the residuals in order to know their errors follow a Gaussian (e.g. goodness of fit). However, this test is not within the scope of this research.

Table 0.8 statistical measures for accuracy when the Gaussian distribution is met.

Statistical measures	Formulas
$RMSE$	$\sqrt{\frac{1}{n}\sum_{i=1}^{n}\Delta {h_i}^2}$
$\bar{\mu}$	$\frac{1}{n}\sum_{i=1}^{n}\Delta {h_i}^2$
σ	$\sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(\Delta h_i - \bar{\mu})^2}$

Source: (Hohle & Hohle, 2009)

Blak (2007) mentions different guidelines where the accuracy of the DEM is given at the 95% confidence level. The formula for computing this accuracy is given as follows:

$$\boldsymbol{Accuracy \approx 1.96 * RMSE} \qquad \textbf{Eq. 0.17}$$

Source: (Blak, 2007)

This vertical comparator can be developed using different approaches. These approaches are discussed next.

1.4.4.2.1 Known points coordinates stored in the database or in a text file

This approach will require storage of some known point coordinates in the database or in a text file, and uploading of DEM or TIN models already created. The GEOWAPP will make a comparison between the known points coordinates and the DEM or TIN, and will provide a report like the one shown in Figure 2.12.

<Standard Deviation>0.05 m </ Standard Deviation >

<Variance>0.224 m </ Variance >

<RMSE>0.070 </ RMSE >

<Mean Error>0.100 ± 0.05 m </ Mean Error >

<Accuracy>0.132 m </Accuracy>

Figure 0.12: This figure shows the proposed report schema after a DEM or TIN has been evaluated.

Also, a text file with the SOGP coordinates can be uploaded. Then, these points might be used to compute the elevation of the known ground point (KGP), using an interpolation method (Ex. Inverse Distance Weighted or IDW). After computing the new interpolated elevation, this can be compared with the KGP Z value of the sample. By applying this methodology, the surveyed area can be tested and the areas accuracy can be shown in a map. This method reduces the complexity of the programing part of this research.

1.4.4.2.2 TIN stored in the application

With this approach, a TIN will be stored the applictaion, and students will upload their SOGP. Then, the GEOWAPP will reply with a similar report than shown in Figure 2.12. However, an outlier evaluator function can be developed.

Outliers are values that cannot be considered as a part of a particular population from a statistical point of view (Aguilar et al., 2007), while blunders are mistakes or gross errors (Wolf & Ghilani, 1997). Wolf and Ghilani (1997) use these terms as synonyms when comes to detecting them. In this research, “blunder” and “outlier” are used as synonyms because these two concepts have too much in common while just looking at the data and since our main purpose is detecting them. If blunders are present, this may be for different reasons: the total station might be malfunctioning; the total station might be erroneously set up; the prism pole might be incorrectly set up in the total station; or the student might categorize a point incorrectly. For example, a point that belongs to an artificial structure might be stored like a GP for generating a DTM.

Blak (2007) states that “a potential blunder may be identified as any error greater than three times the standard deviation (3 sigma) of the error”. This author states also that any check point with a large error should not be discarded without a proper investigation.

Blak also states that for determining vertical accuracy, the check points should be acquired with a method that allows at least 3 times better accuracy than the DEM. This requirement can be used with another approach. If a reference DEM has been determined to have an accuracy X, and new measurements are added with an accuracy Y, these new measurements can be evaluated. An example of these is given in Figure 2.13.

If $X \geq Y$
<message>
The required accuracy is met
Look up the outliers
</message >
Else
<message>
The required accuracy is not met
Look up the outliers
</message >
End

Figure 0.13: this figure shows the report schema 2 for second approach.

The full report for this approach will contain the specified values shown in Figure 2.12, one of the messages of Figure 2.13, and an outlier report shown Figure 2.14.

Outlier report.
< outlier>PT X< /outlier>
< outlier>PT Y</outlier>

Figure 0.14: this figure shows the outlier report schema; PTX and PTY are outliers, which have residuals bigger than 3σ

1.5 Database Design

Although the database for this project is not very complex, it has to accommodate and manage a variety of content like users, accuracies, control points and coordinates of KTFs. The database conceptual design will be described in this subsection.

The database is shown as a whole in Figure 2.15.

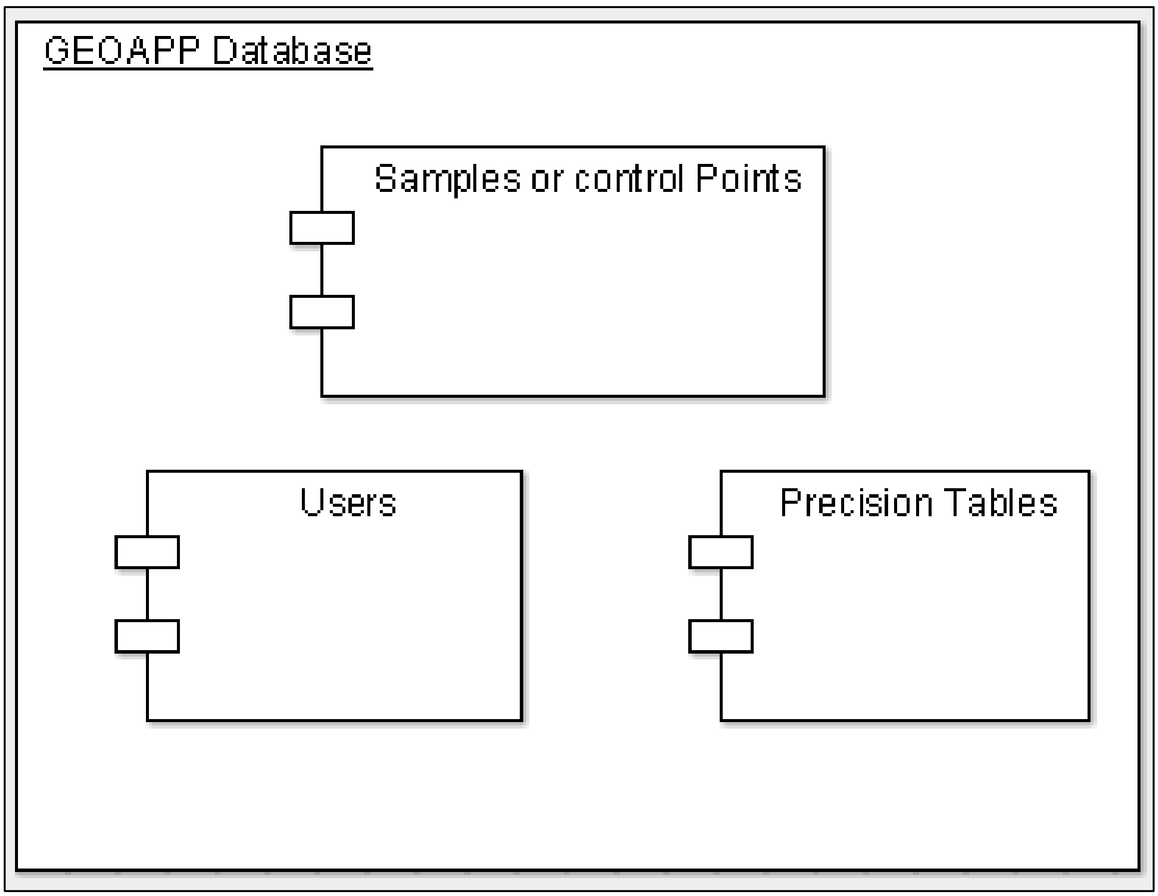


Figure 0.15. Component diagram of the Database shows the classification of the tables that will be stored in the database

The sample and control points will include bench marks, GP, TF, etc. However, when dealing with samples lists like KGP and KTF can also be stored in txt files. The user table will store people who have a specific role: Administrators (Instructors, Teaching Assistants) or Users (Students). Finally, the precision table will have an important role because will set the requirements evaluating the students' work. The table schema will be discussed in the next chapter.

1.6 Authoring tool

The authoring tool will be limited in this research to the task of inserting new data into the Database, as well as uploading new files in order to process the data. However, this option will give freedom to choose new places to hold the survey practicums.

The next chapter will treat the application implementation, including the different technologies that will be used and specific details about the application development. Also, interaction between systems and some results will be shown.

Chapter 3: GEOWAPP prototype development

A GEOWAPP prototype was created to implement the idea developed in Chapter 2. This chapter provides an explanation of the different roles of technologies and algorithms were created for the GEOWAPP. In order to create a web application that processes data, several technologies should be combined. In this instance, technologies like HTML, JavaScript, JQuery, PHP, MySQL, and Python were used to create the GEOWAPP application. Bootstrap was added in order to improve the web application appearance and responsiveness. Table 3.1 shows the technologies used and their role in the application.

Table 0.1: Technologies and functionality

Technology	Function in the GEOWAPP
HTML	Standard language.
JQuery, JavaScript	Managing the contents of the Web interphase: load forms, posting forms, display Google Maps, Display KMLs, etc.
PHP	Creating dynamic forms, formatting information for Python processing, and leveling and traversing processing
MySQL	Managing the user's tables, accuracy tables, code tables.
Python	Vertical accuracy processing and horizontal accuracy processing, creating the KML components.
Bootstrap	Web appearance and responsivity

There are many important considerations while developing a software such as technologies and their role, algorithms, libraries, other applications, physical structure (folder and files), etc. the GEOWAPP physical structure shows the organization of the files that compose the application.

1.7 Application Structure

The GEOWAPP is composed of various independent files. The first file is the *index.php*, which basically provides the interphase of the web application. Then, the application contains 11 folders, which are *Forms, PHPS*, *CSS*, *fonts*, *REPORTS*, *Python*, *uploads*, *img*, *js*, *and KMLS* (see Figure 3.1). Every folder's role is explained next.

Figure 0.1: application folders.

1.7.1 Forms

The Forms folder hosts all forms that are not dynamic. In other words, the forms in this folder do not depend on the information that is provided by the user. Figure 3.2 shows the form for traversing checking, called *form_traverse_type.php*.

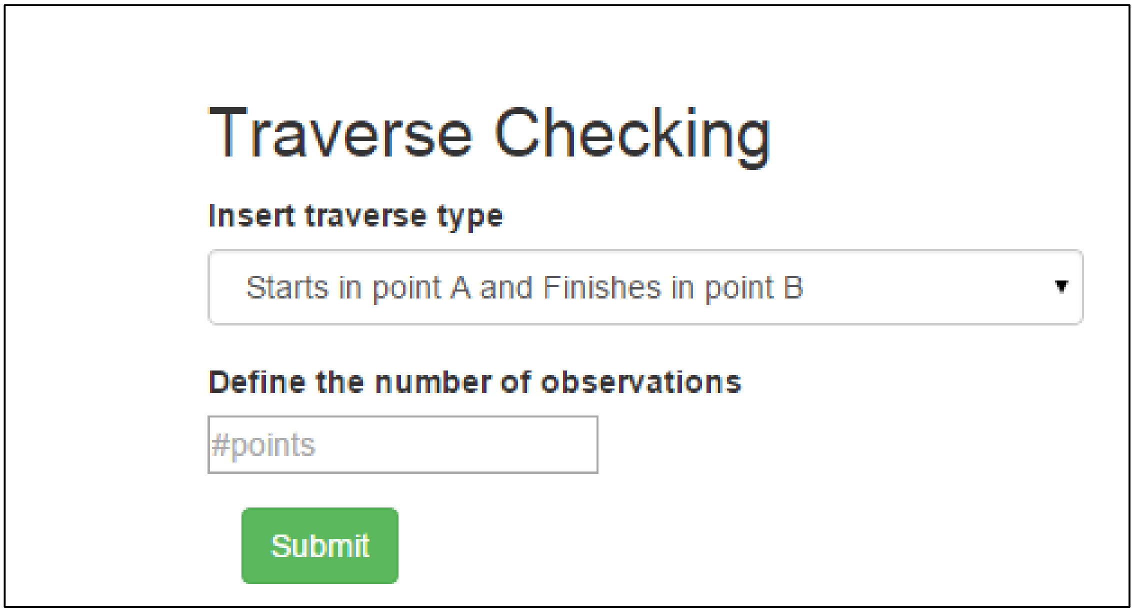


Figure 0.2 The Traverse Checking Form is a static form, which will always display the same information.

1.7.2 PHPS Folder

The PHPS folder contains the dynamic forms and some not computationally demanding scrips such the traversing and leveling computation. The dynamic forms are created because the number points that students measure in their labs varies. For example, the Traversing Checking forms ask for the type of traverse and the number of points (or traverse legs), as seen in Figure 3.2. If the type of traverse is specified as *Starts and finishes in point A* option and number of points is set to 5, the form in Figure 3.3 will be displayed.

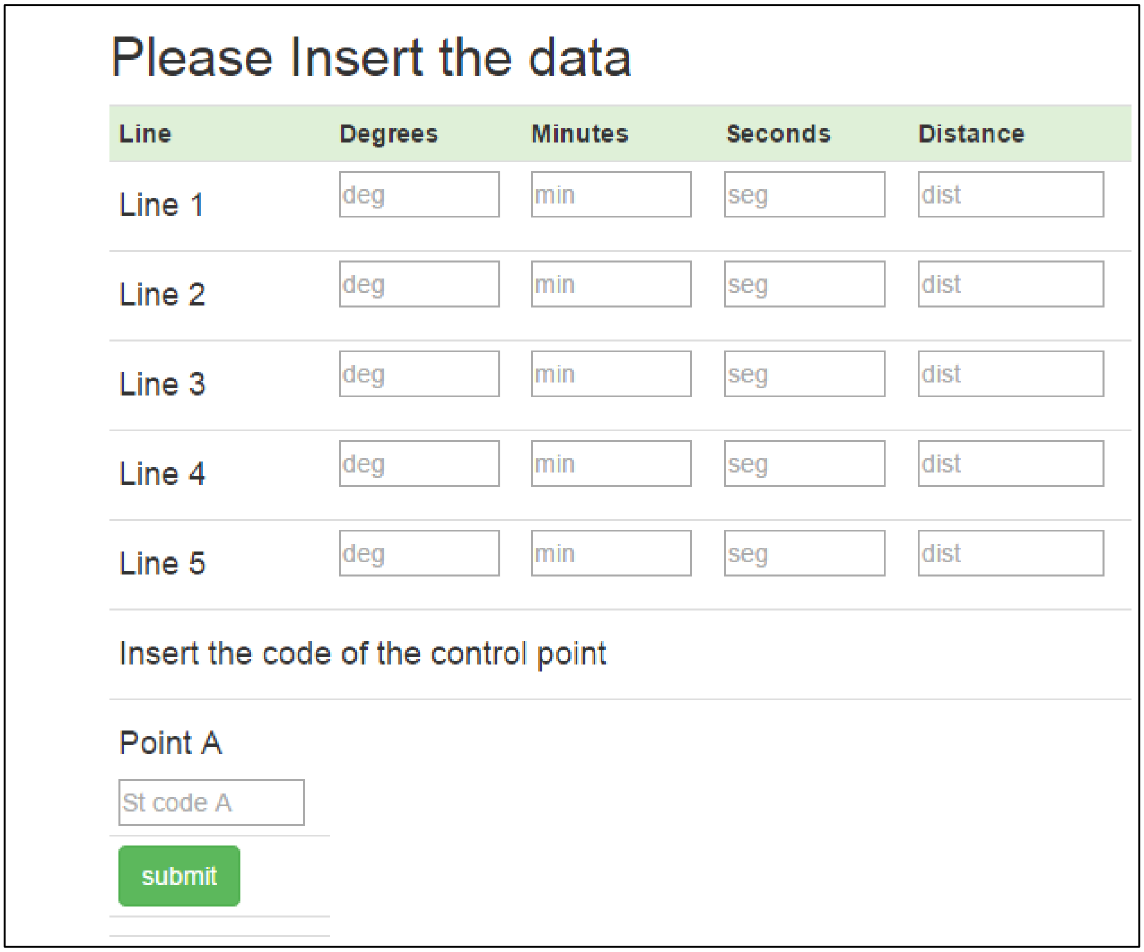


Figure 0.3: This figure shows a form generated dynamically for the traversing checking. If the input values vary in the previous form (Figure 3.2), this form will vary as well.

For traversing checking and leveling differential level checking, the computations are done using a PHP script that is contained in the PHP folder. However, Python is used for a computation that requires a use of matrices and/or elaboration of KML files. In such a case, these PHP scripts just format the information for Python processing. This interaction will be explained later when in this chapter every tool is described.

1.7.3 CSS, fonts, and JS folders

These folders store scripts for formatting and managing contents of the Web application. For example, Js folder contains the library for JavaScript like JQuery, and bootstrap and other plugin. CSS and fonts folders are components of the bootstrap framework.

1.7.4 REPORTS, img, uploads folders, and KMLS

These folders contain different files such as images, text files, and KMLS. The REPORT and KMLS folder store files that were built by the GEOWAPP, processed by Python scripts. On the other hand, uploads folder contains two types of information: samples files (KGP, KTF), which are uploaded for instructors, and students' files, which are the observations for testing. The Img folder contains images like the UNB logo or any other image.

1.7.5 Python Folder

Python scripts are stored in this folder. These scripts carry out the heavy computational part of the application like the Vertical Comparator and Proximity Comparator. The descriptions of the Python algorithms are given in the discussion of each corresponding tool in Section 3.3. Next, the GEOWAPP interface is described.

1.8 The GEOWAPP interface (Index.php)

The Index.php structure is composed of two (2) components: JavaScript or JQuery functions and the user interface. Including content managing functions in Index.php makes the interaction of such an application easier and more understandable. For instance, having functions to load the forms in Index.php is more organized than loading the forms as objects. In this way, all CSS styles are maintained and can be easily passed to other forms. An example of a loading function is shown in Figure 3.4. A web application interface similar to desktop applications is possible using JavaScript. More details about this ability are not given because this is beyond of the scope of this research. Nevertheless, a brief description is treated next.

```
function traversing1(){
    $("#FormDisplayer").load("Forms/form_traverse_type.php");
```

Figure 0.4: this figure shows the loading function, which calls the form displayer and loads the traverse form into the file.

The JS functions in Index.php are divided into two classes; (a) the content manager displays, writes, and posts results in text form; (b) the Google Maps manager displays the results on Google Maps. The next component, user interface, is also divided into two: the navigation bar, and main window. While in the navigation bar users call the functions for processing data and registering, they see the results in the main window. A logical schema explaining Index.php is provided in Figure 3.5. Users will mainly interact with two components of the interface: the toolbar and the form/results displayer.

```
<GEOWAPP interface>
        <Functions>
                <content manager/>
                <Google Maps manager/>
        </Functions>
        <user interface>
                <navigation bar>
                        <registry bar>
                        <Tool bar/>
                </navigation bar>
                <main window>
                        <results displayer>
                                <computational results/>
                                <map results/>
                        </results displayer>
                </main window>
        </user interface>
</GEOWAPP interface>
```

Figure 0.5 the xml schema shows the structure of the GEOWAPP interface. There are two classes of functions: for managing the interface contents and for managing the Google Maps API. Then, there are two main components in the user interface: the tool bar and the results displayer.

Responsiveness allows web applications to have good organization and appearance of information in different devices like cellphone, tables, or computers. The Bootstrap framework were used to add responsiveness to GEOWAPP. Figure 3.6 and Figure 3.7 show different views of the GEOAWAPP depending on the screen resolution.

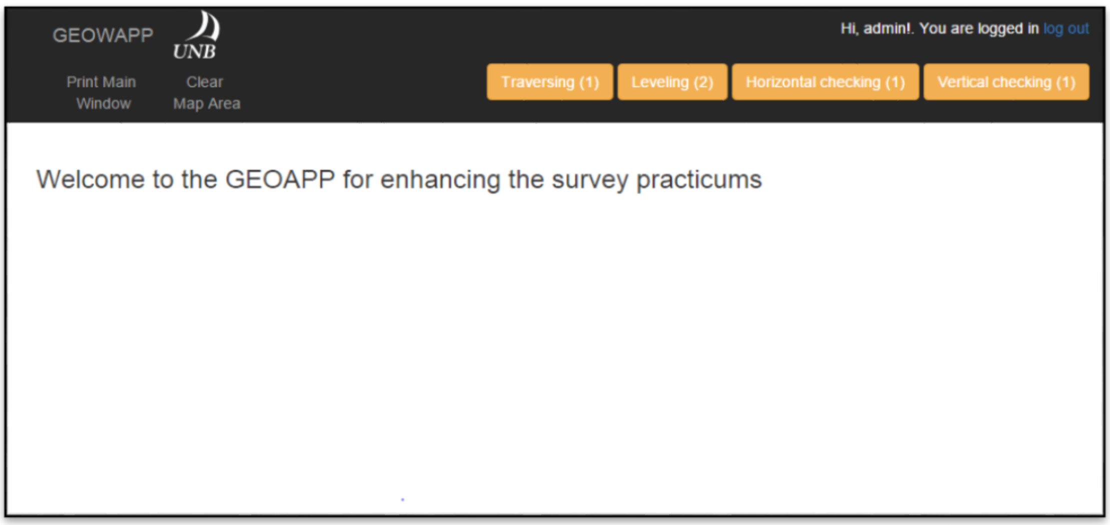


Figure 0.6: this figure shows the appearance of the GEOWAPP in large screens.

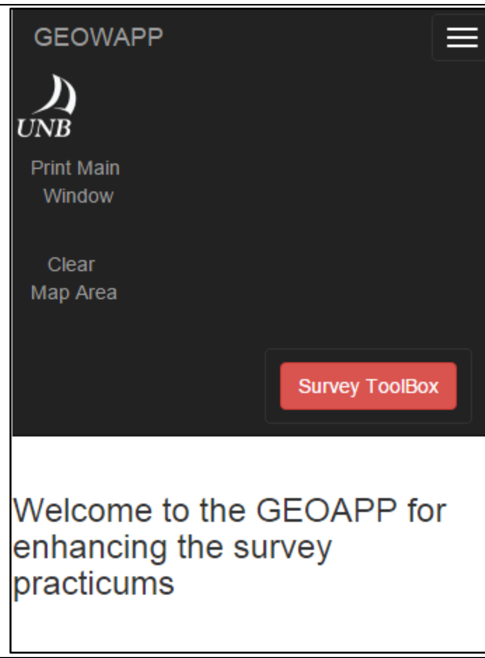


Figure 0.7: this figure shows the appearance of the GEOWAPP in small screens.

The core of this application is contained in the toolbox, which provides the services. Section 3.3 provides a detailed explanation of the toolbox.

1.9 Toolbox

The toolbox is a combination of different scripts, which leads to the display of results. Depending on the tool, these results might be shown numerically or both numerically and graphically. The combination of scripts is described in the following subsections. Six (6) tools were designed (see Section 2.4) but just five (5) tools were developed (Traversing Comparator, Leveling Comparator, Leveling Network Comparator, Proximity Comparator, Vertical Comparator). The Network Comparator was not developed because the prototype's purpose is to test the idea of the web application. Then, the five (5) tools were enough for this purpose. However, the idea may be considered in future research, and then, it is worth to have this tool mentioned in this document. Four (4) out of five (5) tools use MySQL for storing required data. A database management system is an important component in most of the applications. the description of the tools includes the way MySQL is used and Section 3.3.6 shows the tables' schemata.

1.9.1 Traversing Comparator

Traversing Comparator was developed as specified in Section 2.4. As shown in Figure 3.2, the first forms ask for the type of traverse and for the number of points in a traverse. The traverse type either (a) starts and finishes in different stations or (b) starts and finishes in the same station. These two (2) options are graphically shown in Figure 3.8 and Figure 3.9, respectively. These two (2) figures display a traverse synthetically generated with Matlab. After submitting the information, the application creates another form, where students can insert distances and azimuths (See Figure 3.2).

Figure 0.8: this figure shows the first type of traverse, which stars in a point and finishes in a different one. The traverse data shown in this figure was generated synthetically with a Matlab script.

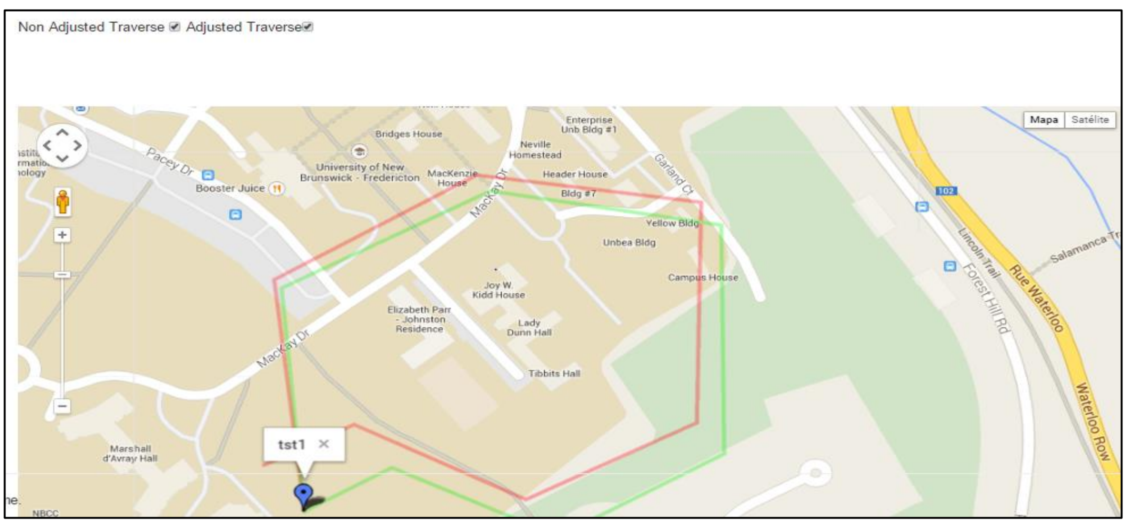


Figure 0.9: this figure shows the first type of traverse, which starts and finishes the same point. The traverse data shown in this figure was generated synthetically with a Matlab script.

In Figure 3.10, the activity diagram shows the information flow through the different technologies: (a) students call the tool, (b) students input the traverse option and the observations, (c) a PHP script creates the dynamic form, (d) a PHP script computes the Bowditch adjustment, (e) a Python script creates the KML files, (f) results are stored and display. This process is straightforward but if a student makes a mistake in imputing the data, the form is displayed again with the inputted data. Then, students can correct the wrong entries and resubmit. Conveniently, the process starts from the Bowditch computation skipping the two previous steps (see Figure 3.10). This is an important characteristic that a web application for teaching must have, because the objective is that students spend time analyzing the results instead of filling forms again. Another important factor is to build the form imitating the conventional format taught in class for booking measurement. Through this standardization, students would not actually need special training for using the tool.

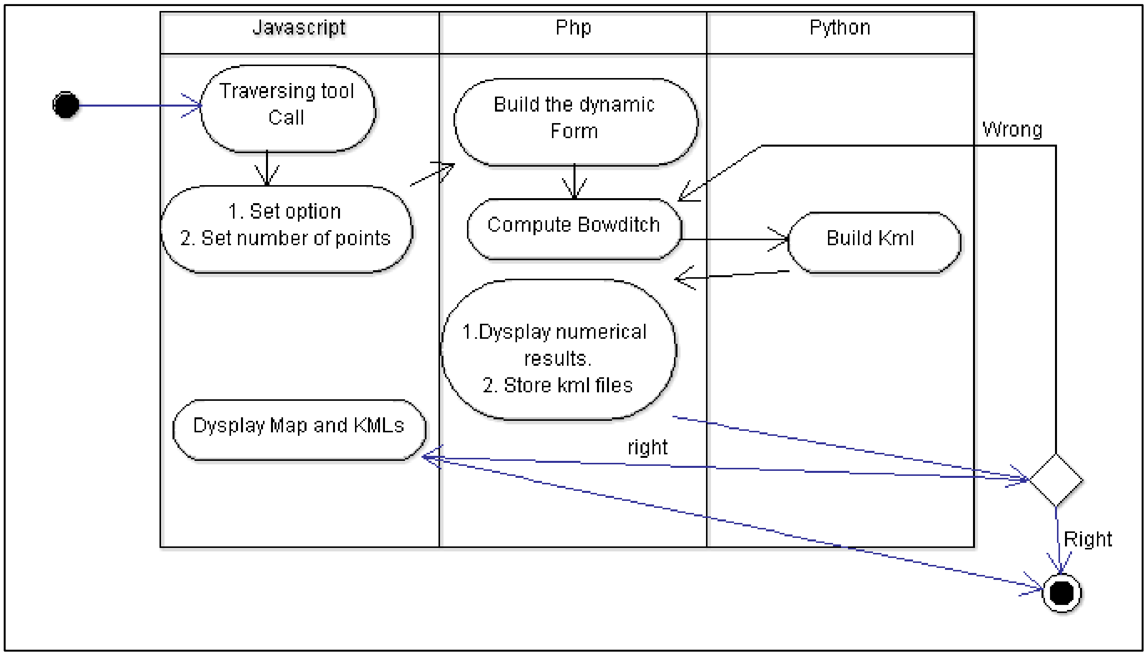


Figure 0.10: the UML activity diagram shows the Traverse tool processing flow as well as the interaction of the different technologies involved, JavaScript, PHP, and Python.

The application requires the codes of the stations used in the traversing exercise. This information will be used for querying the application database. When option A (start and finishes in different stations) is chosen, a modified Bowditch rule is carried out. The residual in the subtraction of the computed ending point and the value stored in the database will be distributed into the traverse stations. On the other hand, option B is a normal Bowditch rule. The stations inserted in the database are in the New Brunswick stereographic projection. In fact, the performance of GEOWAPP depends on all X and Y coordinates for all the tools being in the New Brunswick Stereographic Projection. Then, the coordinates of every traverse leg are converted in geographic coordinates. This transformation is computed using the formulae described by Thomson et al., (1977). The parameters were used for this transformation are shown next:

X0 = 2500000 m coordinate X origin of the projection

Y0 = 7500000 m coordinate Y origin of the projection

R = 6379303.380 m radius of the conformal sphere evaluated in Theta (0)

K0 = 0.999912 scale factor

a = 6378137 m semi-major axis

b = 6356752.3141403561 m semi-minor axis

lat_0 = 46.5^{o} latitude of the origin

lon_0 = -66.5^{o} Longitude of the origin

This transformation function was tested with the Coordinate Transformation Service (CTS) of Service New Brunswick (http://geonb.snb.ca/CTS/). Table 3.2 shows a comparison of the results.

Table 0.2: Comparison of GEOWAPP and CTS transformed coordinates

NB stereographic coordinates		GEOWAP Transformation		CTS Transformation	
Longitude(m)	Latitude(m)	Longitude(°)	Latitude(°)	Longitude(°)	Latitude(°)
7438628.399	2488888.073	-66.64332211	45.94774250	-66.64332211	45.94774250
7438671.222	2488819.478	-66.64420786	45.94812667	-66.64420786	45.94812667
7438699.767	2488827.246	-66.64410833	45.94838363	-66.64410833	45.94838363

Differences between CTS and GEOWAPP	
Lon	Latitude
0	0
0	0
0	0

Finally, Figure 3.11 shows the numerical information when students use Traversing Comparator. In addition, the information in Figure 3.12 will be added to report when an instructor uses the tool. The error message stating that the traverse is off-tolerance was not included in the prototype.

You started and finished in 'tst1'

Residual of departures: -0.026

Residual of Latitudes: 0.006

Linear misclouse: 0.026

Traverse lenth: 116.95

Traverse relative precision 1: 4466

Figure 0.11: students will access this information when they are using the tool by themselves. The residuals, linear misclosure and traverse length are in meters.

--	--	--	Unajusted		Balanced		Coordinates	
Station	Pre. Azimuths	Length	Departures	Latitude	Departure	Latitude	X	Y
tst1	--	--	--	--	--	--	2489045.28	7438030.148
--	270d 29m 22s	14.720	-14.719	0.126	-14.716	0.125	--	--
1	--	--	--	--	--	--	2489030.564	7438030.273
--	253d 21m 14s	17.244	-16.521	-4.94	-16.518	-4.941	--	--
2	--	--	--	--	--	--	2489014.046	7438025.332
--	166d 12m 58s	30.853	7.351	-29.964	7.358	-29.966	--	--
3	--	--	--	--	--	--	2489021.404	7437995.366
--	78d 04m 12s	24.391	23.864	5.042	23.87	5.041	--	--
4	--	--	--	--	--	--	2489045.273	7438000.407
--	00d 00m 00s	29.742	0	29.742	0.007	29.741	--	--
tst1	--	--	--	--	--	--	2489045.28	7438030.148

Figure 0.12: this information will be added to the information displayed in figure 3.11 when an instructor is using Traversing Comparator. The latitudes, departures, distances and coordinates are in meters.

1.9.2 Leveling Comparator

This tool performs a very simple computation for the differential leveling. This computation is performed using a PHP script. The forms are created in a way that matches how students collect data in the field. The process of this tool is simpler than the rest of the tools (see Figure 3.13): (a) students call the tool, (b) set the leveling option and the number of turning points, (c) compute differential leveling, (d) display the leveling results. The first form of the Leveling Comparator asks for two values, the number of forward run stations and return run stations, in order to create the next form that requests the values of the observations. As the Traverse Comparator, this too requests two benchmark's codes used for the leveling exercise. This tool also requests the distance of every reading but if no distance is specified, it will use a constant of 1 km for computing the precision constant (c) (see Section 2.4.2.1). Figure 3.14 shows the results of the Leveling Comparator, which contains a full report for instructors. The database stores a precision table, which contains information about measurement standards. This precision table will be shown in the database schema explanation, Section 3.3.6. The database constant shown in the report is the base of comparison to define the order of accuracy of the leveling exercise. For example, a constant database of 0,12 m means that the leveling is within 2.4 cm and 12 cm. Such a result corresponds to an order of accuracy of fourth class.

Googles Maps were not used for spatial representation in this tool or in the least squares adjustment tool.

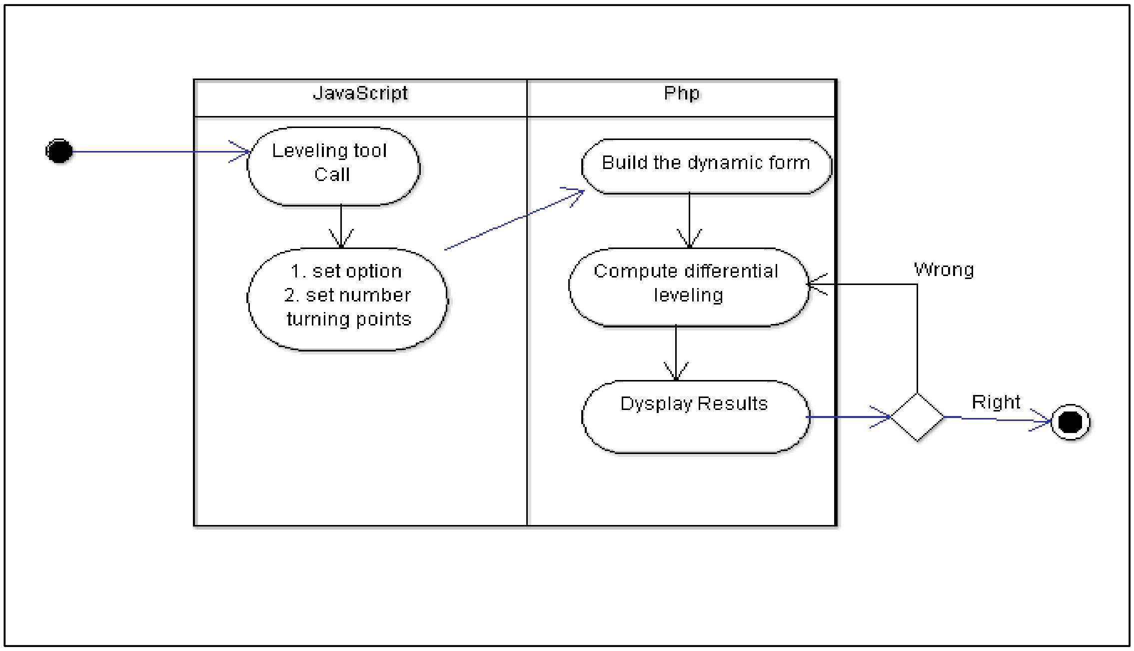


Figure 0.13: the UML activity diagram shows the Levelling tool processing flow as well as the interaction of the different technologies involved, JavaScript, PHP, and Python.

Station	B.S. +(m)	HI	F.S. -(m)	Elevation(m)
BMMIL	0.405	--	--	625.809
--	--	626.214	--	--
TP 1	0.067	--	2.551	623.663
--	--	623.73	--	--
TP 2	0.293	--	2.411	621.319
--	--	621.612	--	--
TP 3	0.140	--	3.572	618.04
--	--	618.18	--	--
BMOAK	3.642	--	2.655	615.525
--	--	619.167	--	--
TP 4	3.825	--	0.796	618.371
--	--	622.196	--	--
TP 5	3.892	--	0.207	621.989
BMMIL	--	--	0.034	625.847

Misclosure: 0.038 m

Distance: 1 km

Precision Constant: 0.038 m

Order of Acurracy: Fourth

database constant: 0.12

BMOAK - Your Value: 0.006

Figure 0.14: the full report, visible just for instructors, is composed of a detailed computation (m) and the piece of information given to students as feedback.

1.9.3 Least squares leveling

The processing used in least squares for leveling is not computationally heavy. However, A PHP matrix operation library is not available for Windows. In response, the Numpy (Numerical Python) library was used for these operations. However, all the matrices and vector formatting is carried out in PHP. The coefficient matrix, observation vector, the weights matrix, and the degrees of freedom are passed to Python through Shell for least squares processing. Python responds with the residuals and results of the processing. Figure 3.15 describes an example of this process: (a) students call the tool, (b) students input the number of equations and set the number of known points, (b) A python script build the dynamic tool, (c) A PHP script format the information to be passed to a python script, (d) A Python script computes a least squares adjustment, (e) display results. Next, PHP displays the results in a table such as the one shown in Figure 3.16.

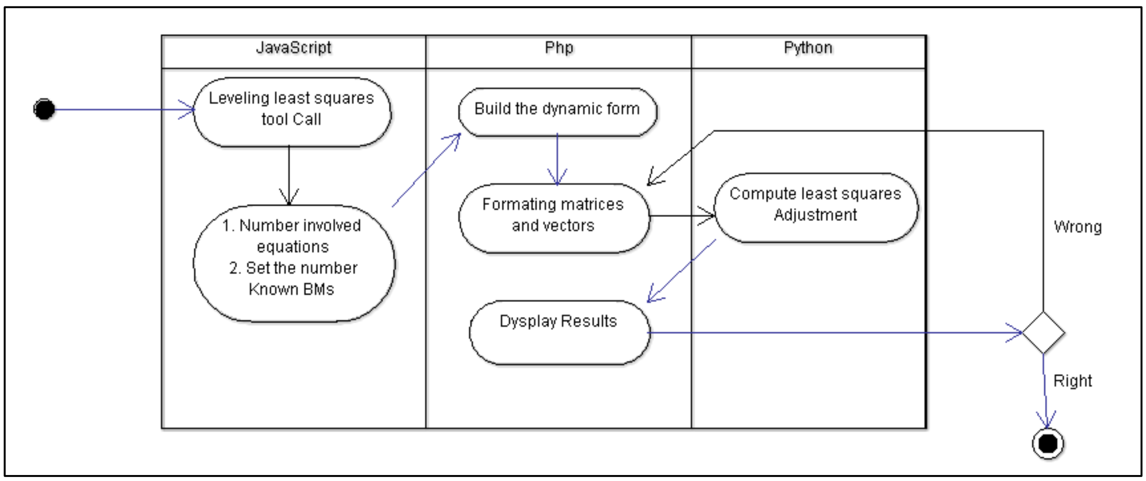


Figure 0.15: the UML activity diagram shows the Least Squares tool processing flow as well as the interaction of the different technologies involved, JavaScript, Php, and Python.

From	to	Dist	Observation Eq	Weight	Residuals
BM1	A	2	796.229	0.5	-0.011
BM2	A	2	796.241	0.5	-0.023
A	B	0.5	3.532	2	-0.008
BM3	B	1	799.739	1	0.003
BM4	B	1	799.728	1	0.014

Station	Elevation	st. dev.
A	796.218	0.01
B	799.742	0.009

Figure 0.16: the first table shows the full report composed by the results of the observation equation (m), weights, and residuals (m). The second table provides the final elevation (m) of the unknown and the standard deviations (m).

1.9.4 Proximity Comparator

The theory for this tool is discussed in Section 2.4.4.1. Here, common parameters are assigned to compute the CEP, which is used to test the points' proximity. For instance, 500m is the longest designed shot, which means that students commonly will not measure longer distances. Next, a Topcon model GTS-105 will be chosen as the instrument that will be used in the field practices, which has an EDM error (see Section 2.4.5) of 2 mm + 2ppm (Topcon Corporation, 2006). This equipment is used in the first survey camps. Finally, the survey accuracy will be 1: 5000; this accuracy sets the internal error using Table 2.6. An example is given next (see Figure 3.17).

Allowed internal angular error (σ_i)

$\tan \sigma_i \approx \ \sigma_i \, rad$

σ_i= 1".39 = 6.7389 x 10^{-6} rad

For 500 m, σ_i is transformed in distance using $\tan \sigma_i = \sigma_{i\ in\ meters}$ /500m $\approx \ \sigma_i \, rad$

$\sigma_{i\ in\ meters}$= 6.7389 x $10^{-6} * 500\ m \approx 0.0034\ m$

EDM Error (σ_{EDM})

EDM = 0.002^2 m + $(\frac{2*500}{1\ 000\ 000})^2$ m = 0.0022 m

EDM Error + angular error

$(\sqrt{\sigma_{EDM}{}^2 + \ \sigma_{i\ in\ meters}{}^2})$

$\sqrt{0.0022^2 + 0.0034^2}$ = 0.004 mm

Figure 0.17: as EDM error (σ_{EDM}) and internal angle error ($\sigma_{i\ in\ meters}$) are independent error, they should be added in square form and then square rooted to compute the magnitude of the error combination.

SFE (4mm) should be added to the computation before for computing the total tolerance. In this instance, SFE is chosen subjectively for reasons specified in Section 2.4.4.1. Table 3.3 shows the Feature Tolerance table, which shows the computation of the total tolerance or CEP (Circular Error Probable) radius.

Table 0.3: computation of the total tolerance. In other words, computation of the CEP radius.

New feature coding system	**Feature type**	**σ_i and EDMs (m)**	**SFE (m)**	**Total tolerance (m)**
BL	Buildings	0.004	0.040	0.0402
BN	Benches	0.004	0.100	0.1001
BR	Bike racks	0.004	0.100	0.1001
Contours	Contour lines	0.004	NA	NA
CB	Curbs	0.004	0.100	0.1001
EB	Electrical boxes	0.004	0.040	0.0402
FN	Fences	0.004	0.040	0.0402
GF	Green fields	0.004	Na	NA
HD	Hydrants	0.004	0.100	0.1001
LI	Lights	0.004	0.100	0.1001
LP	Lamp posts	0.004	0.100	0.1001
MH	Manholes	0.004	0.050	0.0502
PG	Play grounds	0.004	0.100	0.1001
PL	Parking areas	0.004	0.100	0.1001
SI	Signs	0.004	0.100	0.1001
ST	Streets	0.004	0.100	0.1001
SD	Storm drains	0.004	0.100	0.1001
SW	Sidewalks or any type of walkways	0.004	0.100	0.1001
WA	Treed or wooded areas	0.004	NA	NA
TR	Trees	0.004	0.100	0.1001
RW	Retaining Walls	0.004	0.100	0.1001
TP	Telephone poles	0.004	0.040	0.0402

In the application, a similar table will be stored in a MySQL database and the data are retrieved to compare students' observed features coordinates to the known feature coordinates. This table schema is shown in Section 3.3.6. This table is an important element for the performance of this tool because it is the basis of the comparison. Every known topographic feature (KTF) coordinate is compared with the closest student observed topographic feature (SOTF) coordinates with the same codification and tested to determine if it meets the tolerance. The tool stores the KTF coordinates in a folder called horizontal_samples, which is a comma-separated value (CSV) file. For the processing, this tool requires that users upload a CSV file, which contains an ID, X and Y coordinate, and a code. GEOWAPP supports either a comma (,) or a semicolon (;) as delimiters. Both known KTF and SOTF CSV file follow the same format that Figure 3.18 shows.

```
ID,X,Y,code
1,2488884.0185,7438772.7883,BL
5,2488873.3142,7438754.6521,BL
24,2488913.0012,7438731.2904,BL
25,2488917.9676,7438728.8061,BL
```

Figure 0.18: the CSV file has to have the headers. The order of the columns does not matter. The units of the coordinates are meters

After the file is uploaded, this file name and the KTF file name are passed to Python for processing and creating the KML files. Figure 3.19 shows the activity diagram describing the information flow: (a) student call the tool, (b) students input the file and select the KTF file name, (c) a PHP scrips uploads a file, (d) a Python script make the point comparison, (f) the same python script builds a KML and a report, (g) the path of the report and KML files are passed to a PHP script, (h) The KML is displayed on Google Maps and the report can be download.

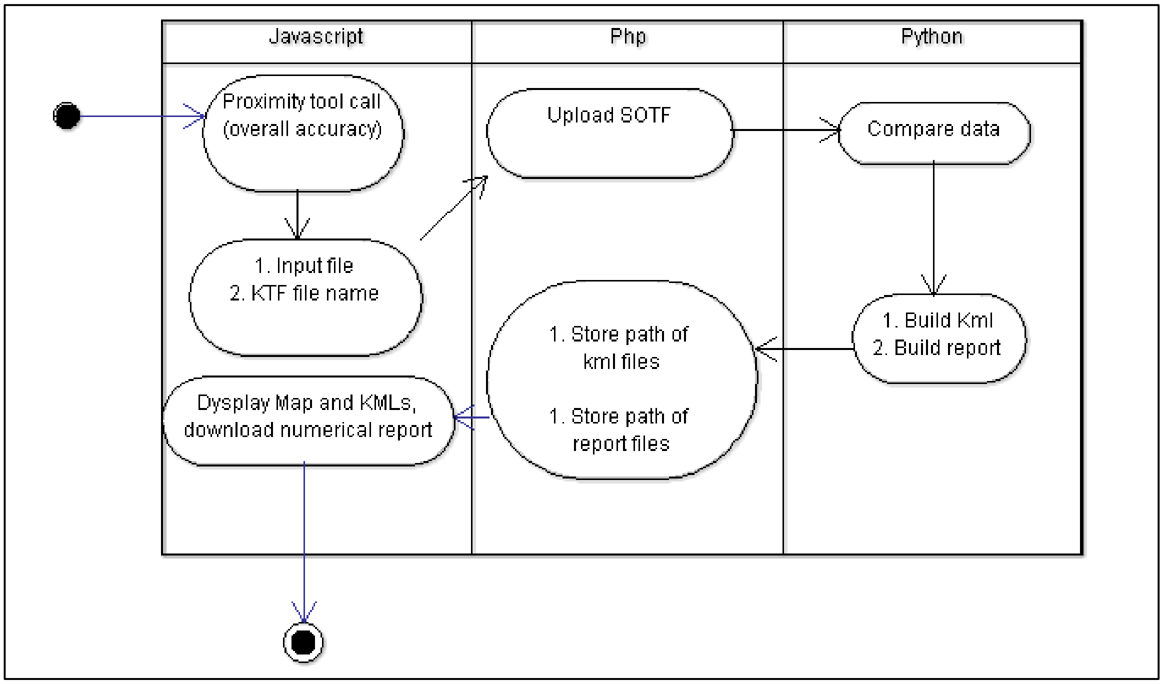


Figure 0.19: the proximity tool is represented with the name of overall accuracy in GEOWAPP. The information flow is straightforward. A student who fails inputting the data has to start again.

The algorithm for this tool is programed in Python because the comparison between points can be computationally demanding. The steps of the algorithm are described next.

1. Load CSV files (KTF and SOTF).
2. Separate vectors (X, Y, ID, and Code) for both KTF and SOTF
3. Query the Feature Tolerance table (MySQL Python connector).
4. Get the feature code tolerance from Feature Tolerance table for every topographic feature (TF) code

5. For every TF code:

    5.1 Create an empty list for the KTF index value.

    5.2 Attach a KTF index value if it is equal to TF code

    5.3 Repeat 5.1 and 5.2 for SOTF

    5.4 For each KTF

        5.4.1 Compute the distance to SOTF

        5.4.2 For each SOTF

            5.4.2.1 Find the shortest distance to KTF

            5.4.2.2 Find SOTF feature index value.

        5.4.3 Compare the shortest distance to the tolerance value and store red if off-tolerance or green if in-tolerance.

        5.4.4 Store the KTF index value

        5.4.5 Store the shortest distance.

        5.4.6 Store the closest index SOTF value

6. Compute the RMS with step five results

7. Transform from NB stereographic to NAD83

8. Create KMLs file and a numerical report.

Figure 3.20, for the graphical representation, and Figure 3.21, for the numerical representation, show examples of the output. These outputs are computed with an artificially generated topographic feature (TF) coordinates. The KML file shows the distance between a KTF and a SOTF when clicking on a pinpoint. Moreover, the green pinpoints are in-tolerance while the red pinpoints are off-tolerance. In the numerical representation, a user can see all the TF involved in the comparison and a computation of the RMS, which is computed from the distances as well.

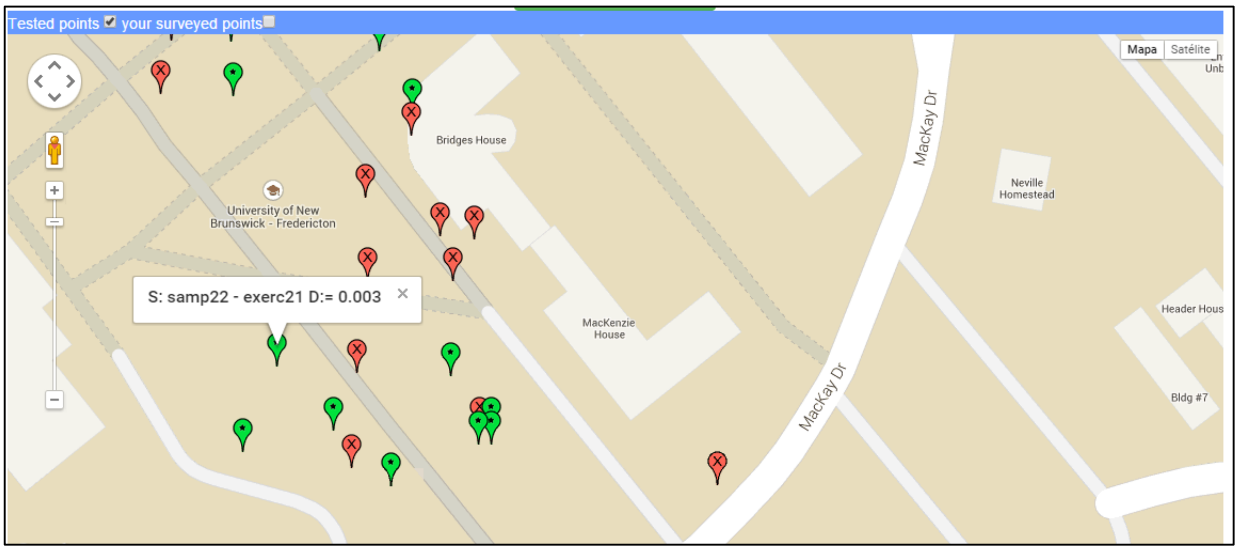


Figure 0.20: the pinpoints represent the known topographic features (KTF). The green pinpoint represent the in-tolerance features while red pinpoints represent off-tolerance features. A textbox shows the distance (m) from a KTF to a SOTF.

```
#sample Point   distance
samp6   exerc31 1.712
samp7   exerc31 0.068
samp8   exerc31 0.022
samp9   exerc31 0.271
samp11  exerc20 0.443
samp12  exerc20 0.013
samp15  exerc18 0.146
samp16  exerc18 0.873
samp5   exerc25 0.91
samp18  exerc16 0.002
samp19  exerc16 0.007
samp20  exerc16 0.006
samp21  exerc16 0.224
samp10  exerc11 0.025
samp14  exerc22 0.747
samp22  exerc21 0.003
samp24  exerc4  1.554
samp25  exerc4  0.231
samp26  exerc4  0.078
samp27  exerc4  0.047
samp23  exerc7  1.142
samp13  exerc5  0.927
samp1   exerc27 0.439
samp2   exerc27 0.008
samp3   exerc27 0.025
samp4   exerc27 0.034
samp17  exerc27 1.27
RMS of the sample = 0.6631
```

Figure 0.21: this report shows the distances (m) from KTF to the closest SOTF with the same codes. At the end, a RMS value shows the quality of the survey.

The numerical report for the Proximity Comparator and the Vertical Comparator were modified due to user reviews of the application. These user reviews were meant to test the acceptance of the tool by students. However, students added useful feedback of what information was missing. These reviews are discussed further in the next chapter.

1.9.5 Vertical Comparator

Section 2.4.4.2 describes a couple of options to create this tool, with a TIN/DEM or with some known ground points (KGP) stored in the application as CSV. This last option was implemented for the prototype because it is easier to program. The CSV files, for both KGP and students' observed ground points (SOGP), have to have at least the following information: an ID, X and Y coordinate, and elevation (Z). Figure 3.22 shows an example of the file format.

```
ID;Y;X;Z
1;7438628.399;2488888.073;46.34
2;7438671.222;2488819.478;46.222
3;7438699.767;2488827.246;41.68
4;7438708.231;2488880.159;37.763
```

Figure 0.22: this CSV file have to have an Id, Y and X coordinate, and height (Z). In addition, the delimiter can be a semicolon (;) or a comma (,). The units of the coordinates are meters.

The information flow is similar to of the Proximity Comparator tool. However, this tool does not need to retrieve any table from the database. The users must provide some information such as KGP file name, the accuracy that is needed, and the number of points used for interpolating the z coordinate of KGP. This information along with the uploaded file is passed to Python for processing, creating the KML files, and the numerical reports. Figure 3.22 shows the form used for gathering this information. This information is passed to Python through a shell command. Next, a Python script returns the names of the KML and numerical report (txt) files to the PHP script, which stores them. The KML files are displayed through JavaScript functions. Figure 3.23 shows this information flow and the interaction of the technologies involved.

Figure 0.23: this report shows the distances from KTF to the closest SOTF with the same codes. At the end, a RMS value shows the quality of the survey.

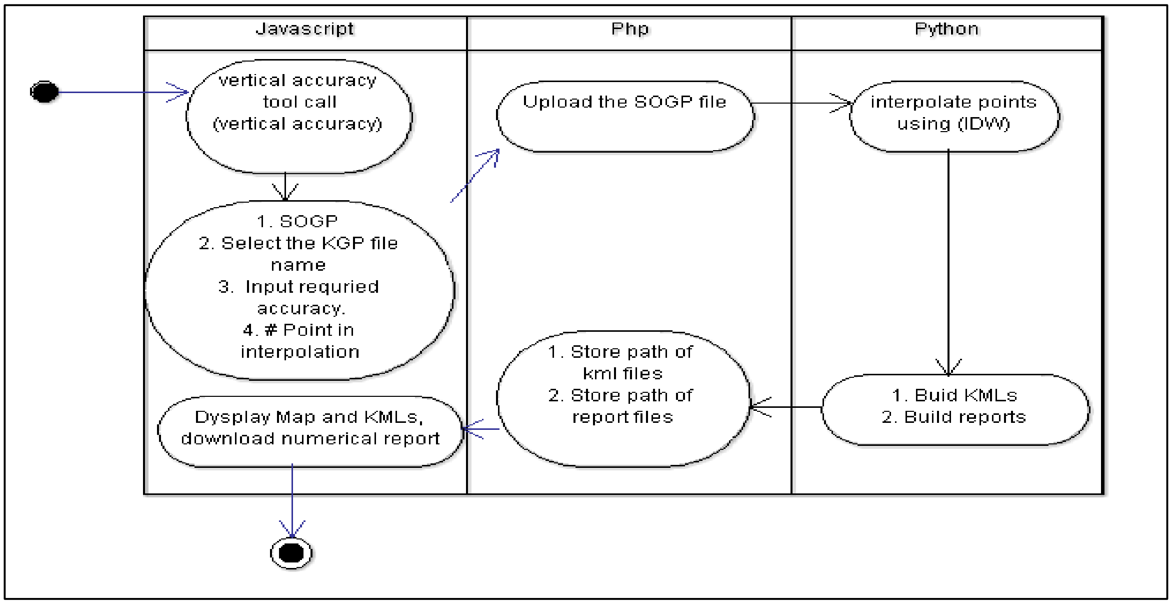


Figure 0.24: Python carries the heavy computation while PHP eases the information flow. On the other hand, JavaScript helps to display the results.

The next steps describe the algorithm that computes the interpolation, and creates the KMLs and numerical report files.

1. Load CSV files (KGP and SOGP).
2. Separate vectors (X, Y, ID, and Z) for both KGPs and SOGPs.
3. Create a dictionary containing the id of KGP, and the id of the closest SOGP.
4. Create a matrix with the closest distances (defined by user) per KGP.
5. Create a dictionary containing the id of SOGP, and the id of the closest KGP.
6. Create a matrix with the closest distances (defined by user) per SOGP.
7. Interpolate the Z value of KGP using step 3 and 4 results.
8. Interpolate the Z value of SOGP using step 5 and 6 results.
9. Compute the residuals and the RMS value for KGP interpolation.
10. Compute the residuals and the RMS value for SOGP interpolation.
11. Create the accuracy polygons using step 3, 7, and 9 results, (Convex hull algorithm is used).
12. Create the KML for students points using steps 5, 8, and 10.
13. Create the other KMLs and reports files.

Figure 3.25 shows an example computed with artificially generated data. There are two interpolations made in this tool as seen in the algorithm steps. First, the KGP height interpolation serves to test the quality of an area height representation and is used to create the accuracy polygons. In this instance, these accuracy polygons are connecting some

SOGP used for the interpolation. A green accuracy polygon means that the interpolation meets the requirement for that zone while a red polygon means the opposite situation. On the other hand, blunder points are located by interpolating students' Z points. For instance, Figure 3.25 shows red or green pinpoints, which are tested students' points. Moreover, Circular Residuals are created to the interpolation of the SOGP to the KGP. In this case, the circular residual are high because the KGP distribution is of poor quality.

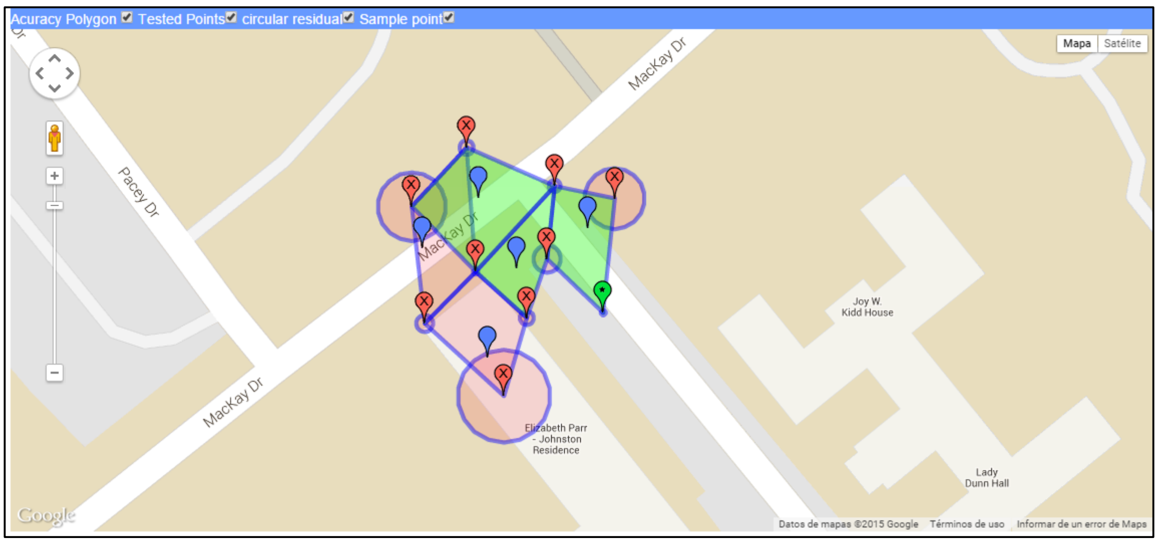


Figure 0.25: the blue pinpoints represent KGPs while the red or green pinpoints represent SOGP. SOGP are the center of the circular residuals. In this case, the accuracy polygons have a maximum number of five (5), number of points used for interpolating plus one (1) , and a minimum number of sides equal to three (3).

In the creation of accuracy polygons, the Convex Hull algorithm (de Berg, Cheong, van Kreveld, & Overmars, 2008) is used to prevent lines to cross each other. Moreover, a

KGP is added as a vertex if it lies outside of polygons composed of the closest SOGP. In this way, the representation of the tested areas is better.

There are two reports because of the two interpolation carried out. A sample Z interpolation report is shown in Figure 3.26. This report shows the ID of KGP and the ID of SOGP used in the interpolation. The report also shows Z known values (Zkn), interpolated Z value (Zint), and residuals (res). In addition, this report includes the RMS value of the interpolation and the residual mean. A similar report is created for SOGP interpolations.

```
#sample PT1     PT2     PT3     PT4     Zkn(m)  Zint(m) res(m)
1       5       2       8       7       100.0   100.739 -0.739
2       2       1       5       7       120.0   100.211 19.789
3       10      5       8       6       105.0   104.059 0.941
4       10      9       5       1       95.0    108.297 -13.297
5       3       6       8       4       99.0    98.523  0.477
Residuals' RMS(m): 11.938
Residuals' mean(m): 1.434
```

Figure 0.26: the report shows the id of the points involved in the interpolation, the KGP Z values (Zkn), the interpolated Z value (Zint), and the residuals (res). In addition, this report includes the RMS value of the interpolation and the residuals' mean

1.10 Database Implementation

In Section 2.5, there are three (3) main groups defining the classification of the database's tables: sample or control points, Users, and Precision tables. As TXT files store sample points (KTF, KGP) in the application, these tables are not implemented in the data base. The database structure is very simple because there is no relationship among the tables. The five (5) tables created for this prototype are benchmark, feature tolerance, leveling precision, stations, and users table. Figure 3.27 shows UML class diagram for these tables used by GEOWAPP. The ID field for the tables is used as an alternative key (<<AK>>), which auto incremental field. There is an ambiguity for the meaning of code. For instance, code means the name of the station or benchmark in the benchmark (bench_mark) or stations (Station) table, while in the Feature Tolerance table (feature_tolerance) is the codification specified in Table 2.3. The precision fields in tables Stations and Bench_marks are standard deviation values associated with the respective coordinates. Finally, the c constant in leveling_precision_table is computed from Eq. 2.6 in Section 2.4.2.1.

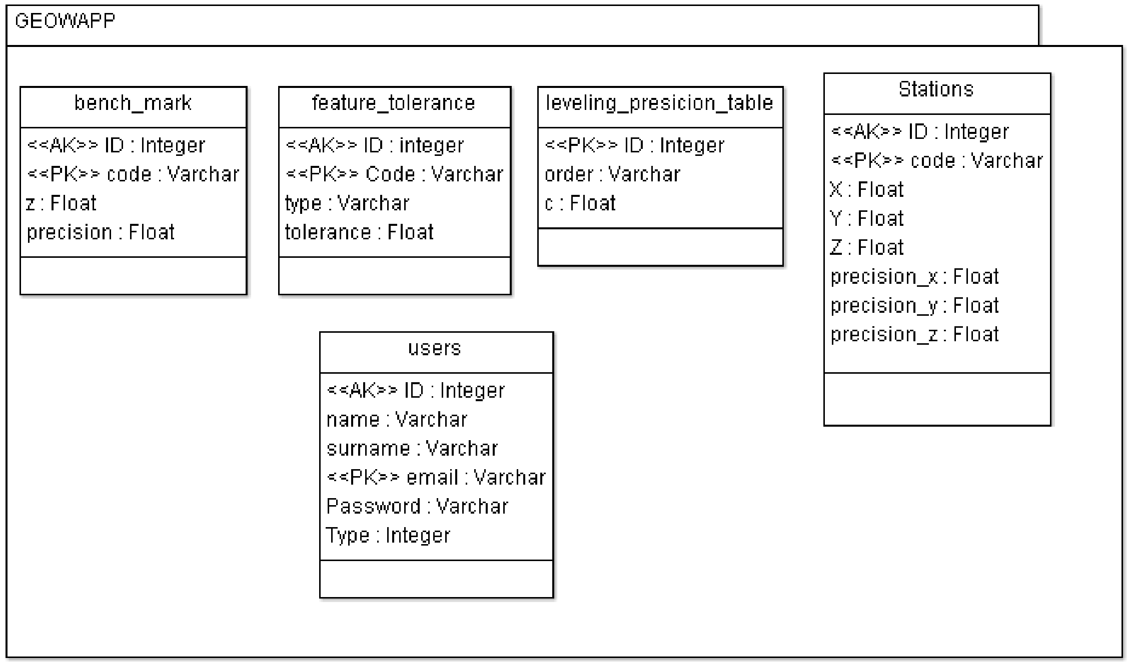


Figure 0.27: <<PK>> stands for primary key while <<AK>> for alternative key. In every table, the name of the field is first specified followed by the field type separated for a colon (:).

Most of the development details were treated in this chapter. However, GEOWAPP has to be tested with real data in order to evaluate the performance and detect problems that may arise while this application is applied to a real course. These topics are discussed in the next the chapter along with the user reviews.

Finally, GEOWAPP was created to be easily deployable. An installation guide is available in Appendix 1.

Chapter 4: Testing and Evaluation of GEOWAPP

In this instance, GEOWAPP was tested using different types of data depending on the tool. For example, exercises data from books were used to test the leveling tools. On the other hand, real data were used to test the Traversing, Proximity , and Vertical Comparator. User reviews were also carried out for all the tools. This chapter summarizes this testing process by tool, as well as analysing their outcomes and weaknesses. The user reviews are addressed at the end of this chapter.

1.11 Traversing Comparator.

Data collected in GGE 2012 (Advanced survey course) were used to test the Traversing Comparator tool. In this case, computations from students were reviewed using this tool. These data are shown in Table 4.1

Table 0.1: students2015 data form GGE 2012.

Station	Azimuth			Dist. (m)
	Degrees	Minutes	Seconds	
1				
	270	29	22.2	14.720
2				
	253	21	14.4	17.244
3				
	166	12	58.6	30.853
4				
	78	04	12.8	24.391
5				
	00	00	00	29.742
1				

There is little difference when comparing the GEOWAPP results to the students' results. For example, the GEOWAPP results show the total traverse length of 116.950 m while students' results show 116.952 m, which is wrong. Likewise, the differences for the latitude's and departure's misclosures are on the order of millimetres. All these differences may be due to rounding errors and some small human errors by students since GEOWAPP was tested using exercises from Wolf and Ghilani (2006).

In addition, a GGE 2012 group of students asked for help because they had a bug in their computations. This situation presented a good opportunity to test GEOWAPP's value for supporting students. The instructor's option was used to create a full report of the computations, which helped these students to confirm that their calculation procedure was right even though the results were still wrong. However, students found by themselves that they flipped some decimals of a distance, which caused the wrong results. This event shows a true advantage of this tool since this kind of error is very difficult to find. Also, these students learned to pay more attention in these kinds of mistakes.

The traverse display on Google Maps shows no difference between the adjusted traverse and non-adjusted traverse. This similarity is due to the small misclosure of the traverse. However, this result was expected since this part of the tool was made to detect really gross errors. Figure 4.1 depicts a situation in which there are two traverse polygons displayed: the adjusted in light green and non-adjusted in red. However, as they are too close to each other, the polygon is a dark green polygon product of the combination of two colours.

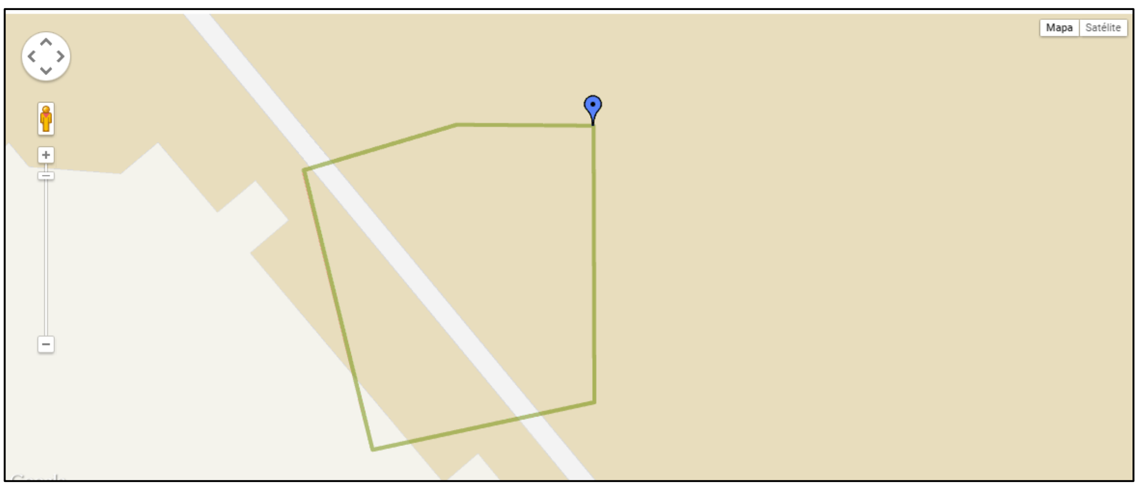


Figure 0.1: the traverse is represented by a KML polyline on Google Maps.

There is another problem with this tool. Since students in GGE 2012 made their measurement without a previously known orientation, the polygon shown in Figure 4.1 is not oriented thus it is not a true representation of the polyline. This situation makes the contextual information from Google Maps less useful. Also, at least one of the traverse points has to be a known coordinate in NB Stereographic double projection. Therefore, some of the course curriculum should be changed in order to include such an application. Moreover, the internal angle method for measuring a traverse is applied in GGE 2012, which requires intermediate computations for acquiring the azimuth and may be cumbersome for students. Thus, a tool should be made in order to test these computations as well.

1.12 Leveling Comparator and Least Squares tool

These tools were tested with book exercises, from Wolf and Ghilani, 2006, and Wolf and Ghilani, 1997. The Leveling comparator tool showed the same values as the book exercise (Wolf & Ghilani, 2006. pp. 107). On the other hand, the Least Squares tool was tested with two exercises (Wolf & Ghilani, 2006. pp. 107; Wolf & Ghilani, 1997. pp. 214). These two exercises are a non-weighted and a weighted exercise respectively. The results of the GEOWAPP computation were the same showing the consistency of the tool.

In theory, the Leveling Comparator tool was developed to test the observation against the computation of misclosures. Also, this tool was designed to test the students' ability to read the rod by comparing students height computation to the height stored in the database. Unfortunately, this assumption could not be tested with real data because this tool was not applicable to GGE courses. On the other hand, the Least Square tool was designed for advanced students. The idea was to provide a tool that could help them to test their measurement in the field. However, senior students have already a good knowledge about gathering measurements. Thus, this tool does not provide any learning value. In contrast, the Leveling Comparator tool may have a teaching value since it is designed for beginners.

1.13 Proximity Comparator tool

The proximity comparator tool was tested with real data, from advanced survey camps of two years, 2014 and 2013. The 2013 data were chosen as KGP stored in the database while 2014 data were chosen as SOGP. Furthermore, just some point codifications were chosen: building (BL), manhole (MH), tree (TR), and lamppost (LP). This decision is due to the non-standardization of the data codification, which makes it difficult to match codes with features, because the 2014 data did not present any legend for its codification. In order to do this test, the 2013 data are assumed to be very reliable and accurate. From Table 2.3, the tolerance values are 0.042 for BL and 0.1001 for MH, TR, and LP. Figure 4.2 shows the results of the dataset comparison.

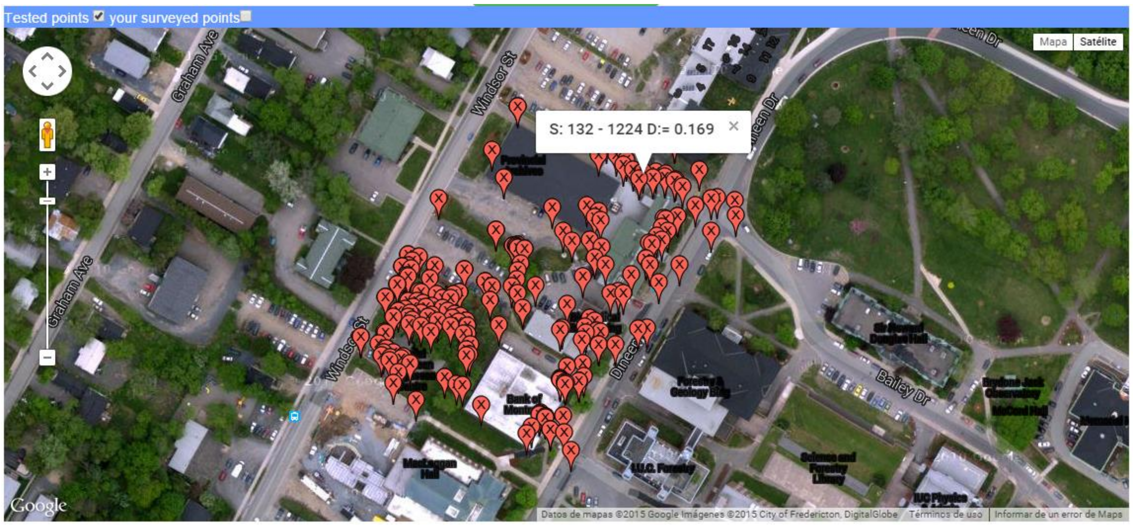


Figure 0.2: the red pinpoints show that no point is within the tolerance. Moreover, the textbox shows how far apart (in m) the KTF with code BL is from a point from the tested dataset.

As seen in figure 4.2, no point from the 2014 dataset is within the tolerance with respect to the 2013 dataset. These results seem like a failure but it provides an insight: there is a mismatch between the two datasets, which means that there is a mistake in the data gathering. Moreover, there are 214 SOGPs being tested. Such a task is impossible to carry out with a traditional reviewing method.

The comparison computation is not computationally demanding. In this instance, there were 9061 comparisons carried out added to three (3) files created with a processing time of 0.1 seconds. This processing time can be improved by adding a data management system and indexes.

On the other hand, there are important details that should be taken into consideration. For example, if a survey involved a determination of some station using

GPS, how to carry out the post-processing is of great importance since the first coordinates might shift the results. However, statistical testing can be applied to find this shift and correct the data, which is possible to implement in this tool.

1.14 Vertical Comparator tool

The same data from the horizontal comparator tool were also used to test this tool. However, these data were formatted differently (see Figure 3.19). In this case, a sample of the 213 KGPs was chosen arbitrarily from the 2013 sample. This KGPs file was composed of ground points (GP) such as PL (Parking areas), WA (Treed or wooded areas) in order to have points representing the ground and not artificial structures. On the other hand, the 2014 data, consisting of 1139 points, were chosen as SOGP and, it was submitted without filtering. For processing these data, the following options were chosen: four (4) closest points for interpolation, and 0.5 m for the required tolerance. In Figure 4.3, there are two accuracy polygons labeled as one (1) and two (2). As seen, the accuracy polygon 1 is off-tolerance. A KGP (blue pinpoint) lies outside of the polygon formed by the four pinpoints used for interpolating the KGP point height. As mentioned in chapter 3, the algorithm adds the KGP point as a vertex in order to represent the area better. On the other hand, the accuracy polygon 2 is in-tolerance, and the KGP point is inside the polygon formed by the four (4) closest points. The processing time was less than four (4) seconds. This time includes the two (2) interpolation and the generation of six (6) files, 4 KMLs and 2 reports.

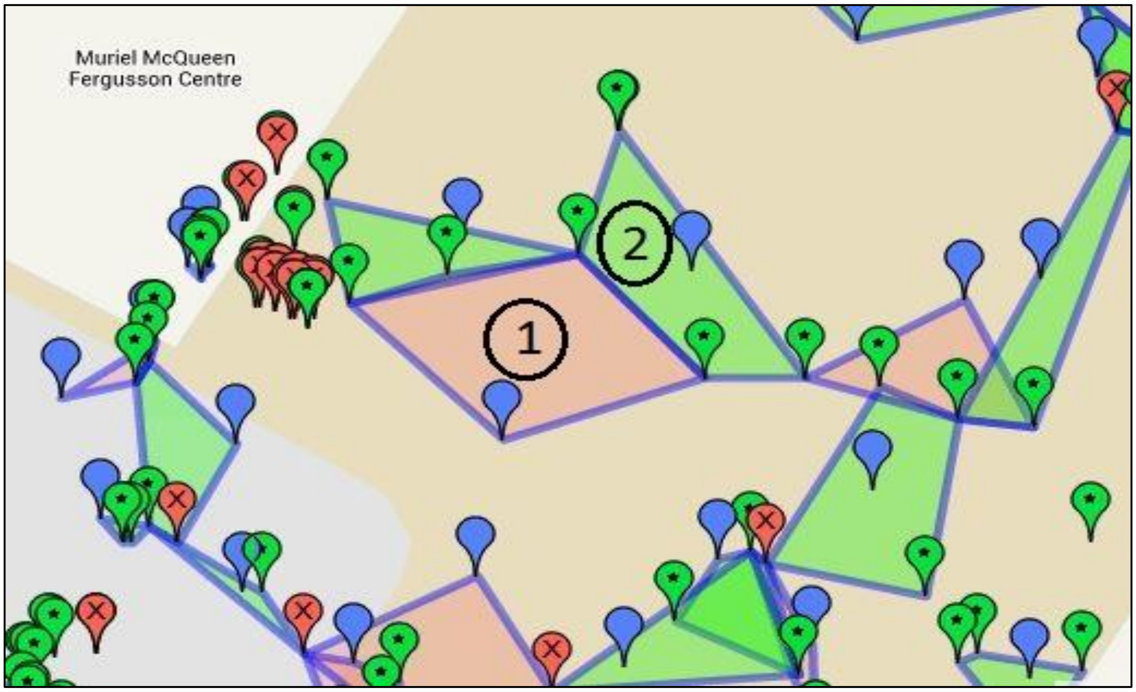


Figure 0.3: the accuracy polygons are built using data from 2013 and 2014 survey practicum as KGP and SOGP respectively. KGP is shown as blue pinpoint while the SOGP is shown as green and red pinpoints.

The quality of SOGPs is derived from the interpolation their Z value from KGPs. However, KGP points are less than SOGPs. Thus, The SOGP interpolation is not as accurate as KGP interpolation. Moreover, SOGP is tested with the same 0.5 m required accuracy, which is an unacceptable error for a student measurement. Because of this reason, the SOGP interpolation will not always give meaningful results. However, these results might be useful if the wrong results follow some patterns. For example, if all the points are off-tolerance, this means that the starting height was wrong. On the other hand, if the wrong results were taken from a specific station and spread through the others, this means that students make a huge mistake inputting this height in the total station. A solution can be separating the two tolerance thresholds into two values, one for interpolating the SOGP and the other for interpolating a KGP. Another solution can be to create a ratio such as a fifth (1/5) or fourth (1/4) of the required tolerance. In any case, the number of points in the KGP file has to be increased and very well distributed to get better results in this computation. The circular residual features are a good representation of the residuals but they have some problems. For example, Google Maps maximum zoom is 20x. At this zoom level, a circular residual of 50 cm is hard to distinguish. Moreover, when there are many points close to each other, the representation is also cumbersome (see Figure 4.4).

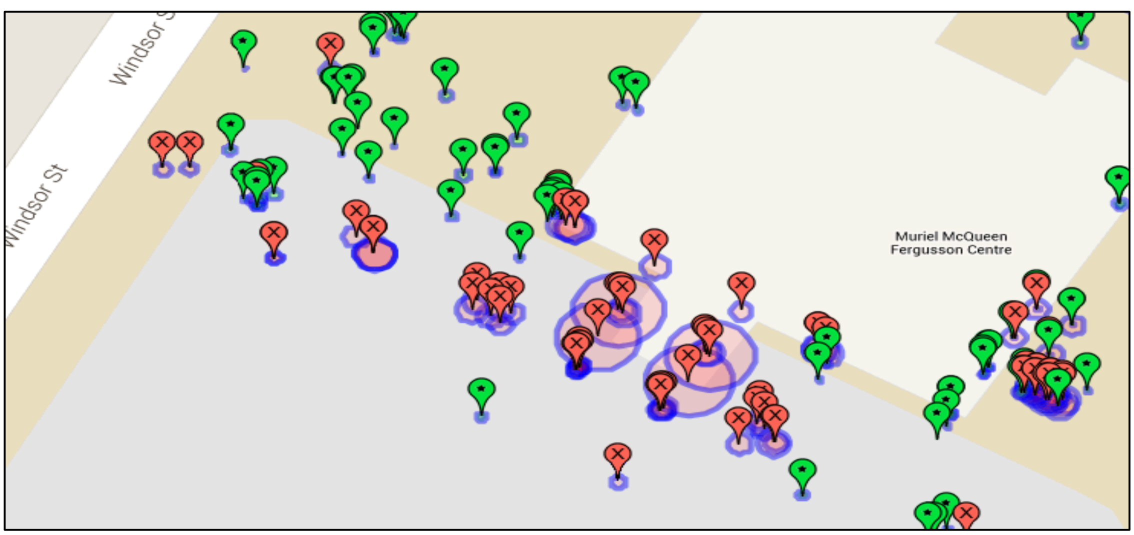


Figure 0.4: the data subject has a circular residual assigned. The in-tolerance circular residual are almost indistinguishable.

KGPs does not need to be a large number of points for measuring the quality of the survey. For example, the RMS value was 0.347 m in this interpolation. This value shows the students survey met the required accuracy. However, this measure has other issues in the data representation. In the current way of representing the quality, a KGP sometimes lie within a dense group of SOGPs. This situation produces a small accuracy polygon, which sometimes is not very distinguishable and meaningful. Also, there are artificial features involved in most of the surveys. These features have to be isolated for a correct interpolation. Thus, the inclusion of breaklines is a necessary approach to make this tool fully operational. On the other hand, different ways of representing the off-tolerance areas should be explored such as a grid or circles surrounding the KGP.

In addition, the satellite view of Google Maps is a very useful tool where students can see the distribution of their survey (see Figure 4.5). The parking lot in Figure 4.5 shows the distribution of the students' survey points using the satellite view. Also, the Google Earth thin client has interesting functionality as well. For example, Figure 4.6 shows a street view of with the accuracy polygon on top of it. The vertices of the accuracy polygons are distinguishable using the KML option "relativeToGround". This option can be expanded to see SOGP position. However, this consideration is beyond the scope of this research.

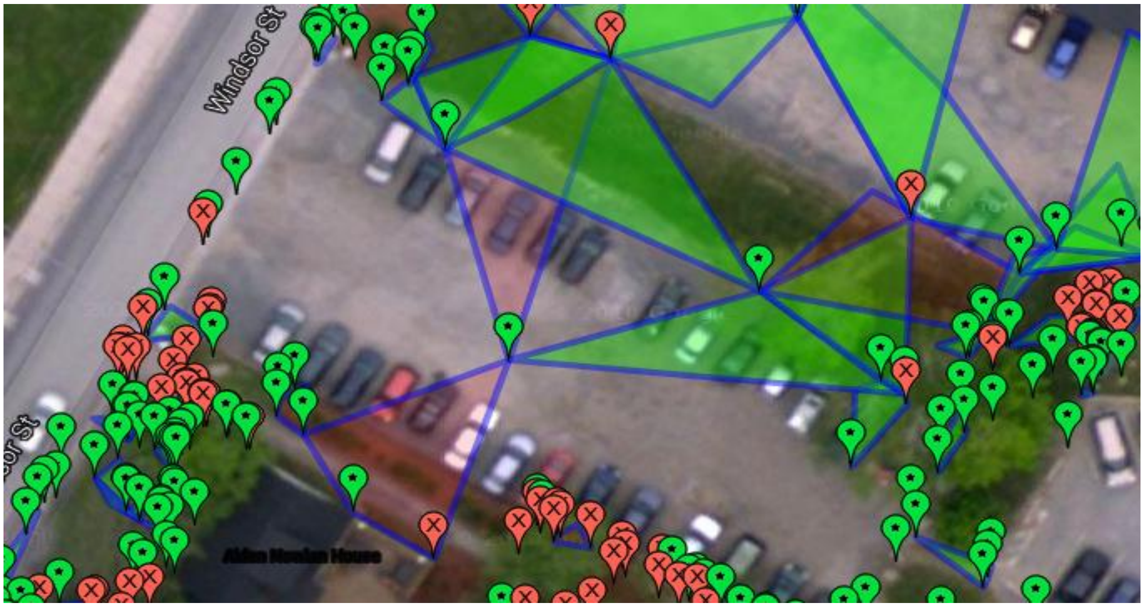


Figure 0.5: Accuracy polygons and the SOGP are shown in the surrounding area of a parking lot in UNB.

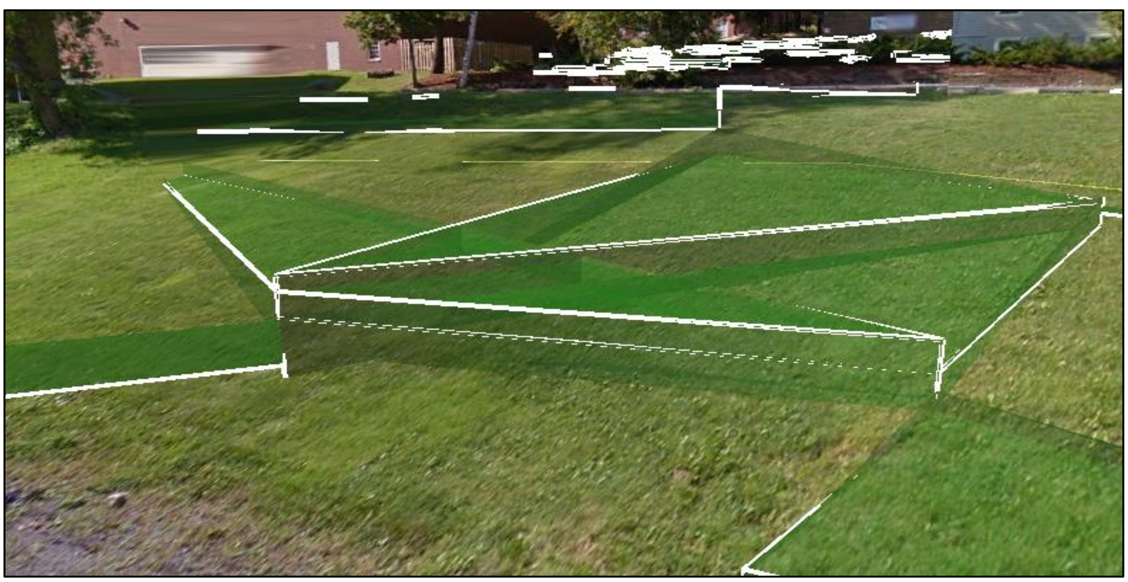


Figure 0.6 : Accuracy polygons are shown on the Google Earth street view option

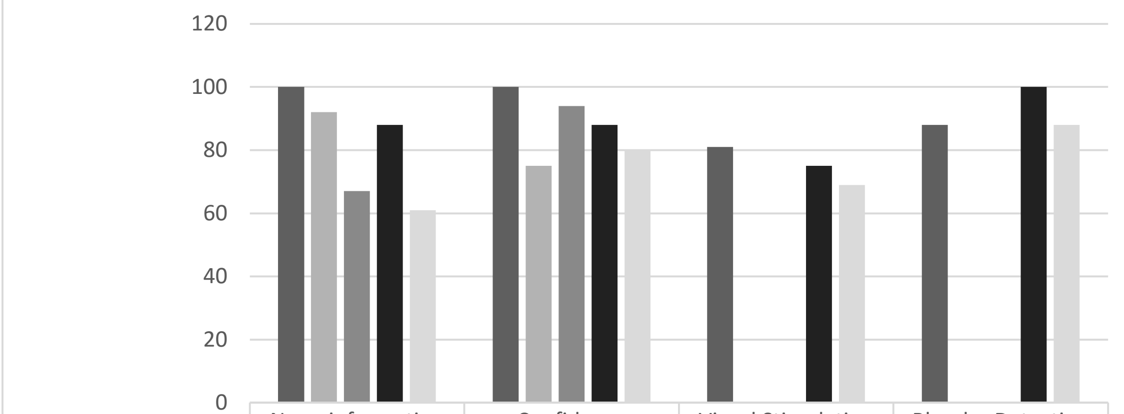
In summary, this tool can be very useful for students and instructors to review the data collection process. Nevertheless, there have to be improvements in the way of displaying which areas are well represented by student survey.

1.15 User Reviews

The user review survey (see Appendix 2) was designed to address three (3) basic aspects: the numerical information provided, the dynamic maps generated, and the application concept. The questions were designed to measure the acceptability of the tool to students. In addition, two open questions were added in order to gather students ideas. This decision turned out to be useful because there were modifications to the tool based on student opinions.

The reviewers were students from the department of Geodesy and Geomatics and other departments at UNB that have to take surveying courses in their curriculum. These students are from all years but the first year. This decision was made because reviewers had to have some experience with field practices in order to give useful feedback. These 17 students were asked to submit some data in one of the tools and answered the survey.

As seen in Appendix 2, students were given a number of options. To analyze students' answers, the option number was divided by the total of options and multiplied by a hundred; The option number was ordered from the worst as one (1) to the best as three or four (3 or 4). This computation will give a value within the range of 25 to 100 for every question in the survey. For charts representation, a mean was computed from the values of students' answers. A value of 50 or less is considered a bad review. All the results of the survey are summarized in Figure 4.7, which contains also a table with the values for every tool.



	Num. information	Confidence	Visual Stimulation	Blunder Detection
Traversing comp	100	100	81	88
Leveling comp	92	75		
Least Squares lev	67	94		
Proximity comp	88	88	75	100
Vertical comp	61	80	69	88

Figure 0.7 The user review results are summarized by question. Also, a table shows the values for every question. The visual stimulation and blunder detection question do not include the leveling tool. In addition, the blunder detection shown in the chart refers to visually detecting them with the aid of the contextual information provided by Google Maps.

The first set of chart columns represents students' feelings for the numerical information displayed by GEOWAPP. In this case, the lowest value is 61 and pertains to Vertical Comparator (See Figure 4.7). Traversing Comparator scores the highest value (100). Users commented that units were not shown when needed, and that more explanation should be provided for interpreting the results of this tool. The second set of columns shows the confidence feeling for having this information while making measurement in the field. In this instance, students' feelings were favorable; the lowest value obtained was 80. In the visual stimulation part, students were asked if the tools would help them to visualize their work more effectively. This question was oriented towards the tools that show results on Google Maps. Thus, the leveling tool was excluded of this measure as seen in Figure 4.7. In this case, the lowest value is 70, which implies that students think that this would help to visualize their work. The last set of columns from Figure 4.7 shows that students also feel that the results displayed on Google Maps will help them to detect blunders. This statement is made based on the lowest value of 88, which is a high value.

In the survey, a question was included to measure students' feeling about a web application for enhancing survey labs. In this instance, the entire set of tools can be analyzed together because the question is highly generalized. Moreover, the choices in the survey were meant to measure if students can be engaged by such an application. In this case, students showed high interest in this application. Figure 4.8 compares the values obtained by each tool with the overall value, which is 85.

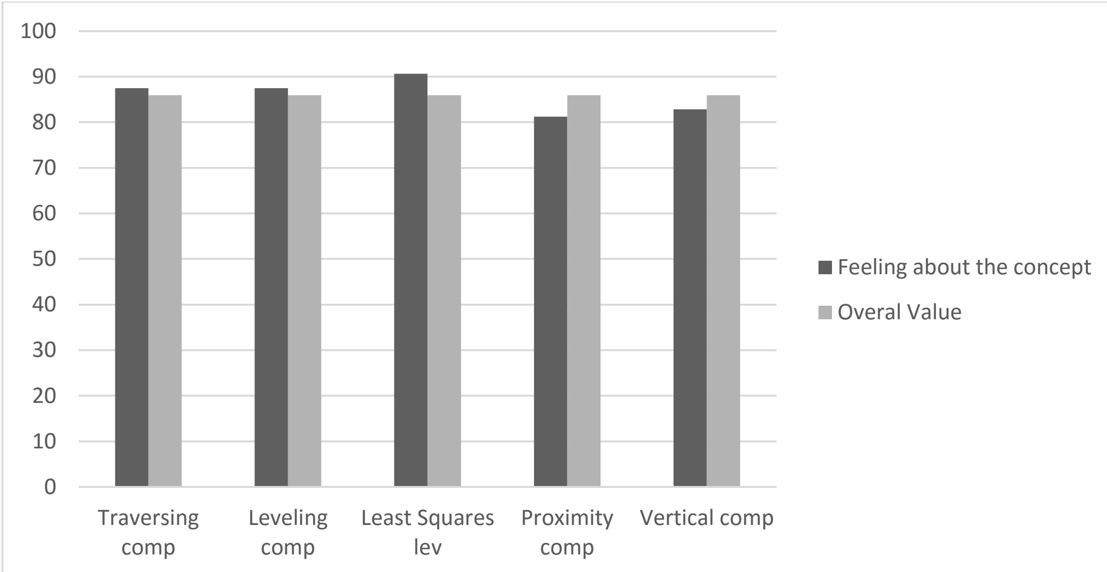


Figure 0.8: students' feelings about the concept is shown in this chart. The dark column shows the evaluation of every tool while the lighter one shows the mean value that includes every tool.

High acceptance of this tool by students can be concluded based on the user reviews. However, this result does not mean that the application is fully operational or that this will increase the learning of students. These topics should be investigated in future research.

Chapter 5: Discussion on the outcomes.

At the beginning, the hypothesis discusses enhancing teaching in survey lab practices by utilizing a web tool. In order to prove or disprove this statement, the GEOWAPP should be applied to a surveying engineering course in real life. This test was not carried out in this research because the application was not ready to fully support the survey practices. On the other hand, there was a hint of GEOWAPP's enhancing characteristic discussed in Section 4.1 where students received beneficial feedback in a traverse practice. Moreover, Davis (2009) mentioned that mobile technology helps to create dynamic and interactive environments inside and outside the classrooms. Motivating students is also a challenge for instructors. Davis (2009) also advises the use of strategies to engage students to learn. Since students show great interest in the GEOWAPP concept (see Figure 4.8), this application can be a way to motivate students. Also, GEOWAPP is designed to give feedback to students. This characteristic is of great importance since, in fact, feedback is a very important component of the teaching process. This reasoning supports the belief that such an application can enhance learning and be beneficial for students.

The designing process took into account the interaction of the instructors and students with GEOWAPP. This design is still valid since instructors should be able to author the exercises. However, instructors have to have some knowledge about the application and MySQL to post exercises in the current state of development of GEOWAPP. Also, the interaction of the GEOWAPP components was modeled (see Figure

2.2). In this instance, the document catalog was not developed for the prototype. However, this component is easy to program since it is just a repository of exercise examples. On the other hand, a repository of exercise examples might be unnecessary because the Desire2learn management system serves this purpose already.

The exercise schemata were designed based on an analysis of GGE 1001 (Introduction to Geodesy and Geomatics), GGE 1803 (Practicum for Civil Engineers), and GGE 2013 (Advanced Survey Practicum). This analysis suggests that the best way to enhanced survey practicums is being able to test accuracies of students' deliverables in different ways. By self-testing, students will gain confidence in their work if the results are correct. In the other case, students can locate where mistakes are made in observations or computations. Thus, accuracy was the pillar for designing and developing GEOWAPP. However, exploring other options can be beneficial for students as well. For example, applications that help step-by-step students to make computations or help to model different situations (e.g. traverse, leveling exercises) can be an interesting approach.

Five (5) out of six (6) tools were designed because the network comparator is beyond the scope of the purpose of the prototype. However, this tool can be can be worth to consider in future developments. For this reason, the design of this tool remains in this document. The application design has more information that what was developed in the prototype to serve for future guidance. For example, the use of DEM is mentioned as an alternative to testing students' datasets. An important aspect that must be considered for future developments is the creation of forms that simulate the standard booking techniques. This consideration will reduce the amount of training for using the tools. A prototype was developed using mainly PHP, Javascript, and Python. This decision is not restrictive because there are many other combination of scripting languages. However, the processing time for the most time consuming task was less than 4 seconds. This result is efficient considering that a data management system was not used in its full capacity of interaction. Thus, the chosen combination of technologies is still a valid option. The Google Maps API was chosen in order to display the results. However, the OpenLayes API is also a valuable option to explore.

A course curriculum should change in order to include a web application such as GEOWAPP. These changes were described in Chapter 4. Also, accurate data must be collected in the place where students usually have their practices. This task can be time consuming but it can also be a one-time task if the monuments of the control points are well maintained and thus their coordinates can be actualized every year. In fact, accurate data are the basis that supports GEOWAPP and any similar application. An example is shown in Section 4.3 where no point was found within tolerance. Maintaining these data would not be a problem because data surveyed by students in the practicum can be used to do so. On the other hand, the SFE (specific feature error) must be determined for unexperienced observers in order to set realistic tolerances for every TF.

New ways of representing the tested areas must be explored since accuracy polygons do not always give the best representation. Circles surrounding the KGP or a grid representation stand as options to be developed.

The Least Squares Levelling Checking tool was considered inapplicable because this tool was designed to give support to advanced students, which have already a good knowledge of data collection. Thus, this tool does not provide a high teaching value. The Leveling Comparator theoretically seems promising. Nevertheless, this might be not the case since the computation of differential leveling is too easy. On the other hand, a dynamic graphical representation of the computation could help students to visualize leveling exercises.

The Traversing Comparator tool can help students to visualize their field work. This tool showed the most promise because it was used to support a real exercise. On the other hand, it can also be extensible to reduce internal angle measurement to azimuths where students often have miscomputations. In the same way, the design of the toolbox allows to add more tools to the application whenever it is considered proper. Then, the application can be easily extended to support more exercises.

From the user reviews, students showed positive feelings for such an application and its capabilities. This tendency does not necessarily mean that students believe that GEOWAPP is ready to be applied in a course. However, students embrace the idea of an application supporting surveying field practices.

Chapter 6: Conclusions.

This study explored the idea of creating a web application that can actively support students in surveying field practices. This exploration comprises a process of designing, creating, and testing this application compliant with the research objectives (RO1 to RO6) (Section 1.3.3). In the designing process, (RO1) the interaction of the different users (students and instructors) was modeled resulting a model of the application components. (RO2) GGE 1001, GGE 1803, GGE 2013 course outlines were reviewed resulting in exercises that could be supported by GEOWAPP. (RO3) The accuracy concept was chosen as the GEOWAPP pillar, which leads to design how field practices can be supported, which was discussed in Chapter 2. (RO4) The next step was to create a GEOWAPP prototype in order to explore if this application produced meaningful results using real data. Based on the model of application components, the technologies PHP, JavaScript, MySQL, and Python were chosen for the GEOWAPP development. On the other hand, different combination of technologies are not discarded for the development of such an application. The Google Maps API was chosen in order to display the results. However, the OpenLayes API could be also a valuable option to explore. There were six (6) tools designed and five (5) developed (See Chapter 5): Traversing Comparator, Leveling Comparator, Least Squares Checking, Proximity comparator, and Vertical Comparator. How to interpret the application results has been discussed in Chapter 4. (RO5) The application functionality was tested with real data and with textbook exercises. The functionality provides the expected result from the design process. However, Least Squares Checking was not found to be applicable, and the value of Leveling Comparator remains untested. Traversing Comparator appeared to be the most promising tool because a teaching value was found. When testing Proximity Comparator with real data, no point was found within the tolerance. This result showed that the data that are used as known topographic feature (KTF) have to be highly accurate and reliable. The Vertical Comparator showed a great potential locating areas that are not well represented by student observed ground points (SOGP). However, Accuracy Polygons appeared to have some deficiencies such as area representation. Also, the density and distribution of the KGP has to be appropriate in order to provide meaningful results. (RO6) Users reviews showed the positive feelings that students have for such an application and its concept. However, this application is not ready to be applied to a real course until some small changes are made to the course curriculum. For instance, giving real starting coordinates and a backsight are necessary for most of the tools. Also, accurate data from the survey location has to be gathered for accurate comparisons. The hypothesis stated was not proved to the fullest extent because this must be tested with a surveying course. However, the application is compliant with techniques for enhancing teaching, and the traversing tool was used to solve a real life problem. Thus, this application has teaching value. In addition, the design of GEOWAPP allows adding more tools to the toolbox, which makes the application extensible. This consideration was a part of the hypothesis, which was achieved. In future work, some features remain to be developed such as a tool that includes internal angles reductions. Different representations of tested areas for Vertical Comparator remain to be evaluated such as a grid or circles surrounding the KGP. Also, the inclusion of breaklines in the solution should be developed for this tool. Other improvement recommendations can be found in Chapter 4. The SFE remain to be determined for inexperienced observers. Generally, this application must be tested with a real life course assessing the students that use the GEOWAPP and students that do not in order to prove if this application is advantageous for students. Finally, other application focus could be useful. For example, an application that focuses on teaching how to make either computation or observation step-by-step would have a worthy value.

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Appendices

1.16 Appendix 1: GEOWAPP installation.

This guide will provide the necessary knowledge to make the GEOWAPP operational

Step 1. PHP installation.

1. Download the MapServer the executable from following the website link: http://www.maptools.org/ms4w/index.phtml?page=downloads.html.

Step 2. MySQL installation and setting.

1. Download MySQL community edition in the following link http://dev.mysql.com/downloads/windows/installer/.
2. Create a generic user and password(e.g. user: geoquerrier password: los3chiflados). Do not use this example exactly because it will cause security problems. Also, remember write down the chosen user and password because they are needed in setting up the application.

Step 3. Download Python.

1. Download Phyton version 3.3. The installer for Windows can be downloaded from the web link: https://www.python.org/download/releases/3.3.0/.
2. Create a folder called Python33 in C drive.

Step 4. Download Python libraries and connectors.

1. Download MySQL python connector using the following web link: http://dev.mysql.com/downloads/connector/python/2.0.html, and Install.
2. Download the NumPy Library from the following link: http://sourceforge.net/projects/numpy/files/NumPy/1.9.2/, and Install.

Step 5. Copy and paste the GEOWAPP in the htdocs folder.

1. For downloading the software, send an email to jaimegarbanzo@gmail.com to request the software.
2. Unzip the folder and paste its contents in the following directory: C:/ms4w/Apache/htdocs/

Step 6. Create the database and the tables.

1. Create a file name geowap.sql using notepad and copy and paste the following commands:

```
CREATE DATABASE  IF NOT EXISTS `geowapp` /*!40100 DEFAULT CHARACTER SET utf8 */;
USE `geowapp`;
-- MySQL dump 10.13  Distrib 5.6.17, for Win32 (x86)
--
-- Host: atlas.gge.unb.ca    Database: geowapp
-- ------------------------------------------------------
-- Server version	5.6.21-log

/*!40101 SET @OLD_CHARACTER_SET_CLIENT=@@CHARACTER_SET_CLIENT */;
/*!40101 SET @OLD_CHARACTER_SET_RESULTS=@@CHARACTER_SET_RESULTS */;
/*!40101 SET @OLD_COLLATION_CONNECTION=@@COLLATION_CONNECTION */;
/*!40101 SET NAMES utf8 */;
/*!40103 SET @OLD_TIME_ZONE=@@TIME_ZONE */;
/*!40103 SET TIME_ZONE='+00:00' */;
/*!40014 SET @OLD_UNIQUE_CHECKS=@@UNIQUE_CHECKS, UNIQUE_CHECKS=0 */;
/*!40014 SET @OLD_FOREIGN_KEY_CHECKS=@@FOREIGN_KEY_CHECKS, FOREIGN_KEY_CHECKS=0 */;
/*!40101 SET @OLD_SQL_MODE=@@SQL_MODE, SQL_MODE='NO_AUTO_VALUE_ON_ZERO' */;
/*!40111 SET @OLD_SQL_NOTES=@@SQL_NOTES, SQL_NOTES=0 */;


--
-- Table structure for table `bench_mark`
--

DROP TABLE IF EXISTS `bench_mark`;
/*!40101 SET @saved_cs_client     = @@character_set_client */;
/*!40101 SET character_set_client = utf8 */;
CREATE TABLE `bench_mark` (
  `ID` int(11) NOT NULL,
  `code` varchar(5) NOT NULL,
  `z` float NOT NULL,
  `precision` float NOT NULL
) ENGINE=InnoDB DEFAULT CHARSET=utf8;
/*!40101 SET character_set_client = @saved_cs_client */;

--
-- Table structure for table `feature_tolerance`
--

DROP TABLE IF EXISTS `feature_tolerance`;
/*!40101 SET @saved_cs_client     = @@character_set_client */;
/*!40101 SET character_set_client = utf8 */;
CREATE TABLE `feature_tolerance` (
  `id` int(11) NOT NULL,
```

```
  `code` varchar(10) NOT NULL,
  `type` varchar(20) NOT NULL,
  `tolerance` float NOT NULL
) ENGINE=InnoDB DEFAULT CHARSET=utf8;
/*!40101 SET character_set_client = @saved_cs_client */;

--
-- Table structure for table `leveling_precision_table`
--

DROP TABLE IF EXISTS `leveling_precision_table`;
/*!40101 SET @saved_cs_client     = @@character_set_client */;
/*!40101 SET character_set_client = utf8 */;
CREATE TABLE `leveling_precision_table` (
  `ID` int(11) NOT NULL,
  `order` varchar(30) NOT NULL,
  `c` float NOT NULL
) ENGINE=InnoDB DEFAULT CHARSET=utf8;
/*!40101 SET character_set_client = @saved_cs_client */;

--
-- Table structure for table `stations`
--

DROP TABLE IF EXISTS `stations`;
/*!40101 SET @saved_cs_client     = @@character_set_client */;
/*!40101 SET character_set_client = utf8 */;
CREATE TABLE `stations` (
  `ID` int(11) NOT NULL AUTO_INCREMENT,
  `code` varchar(5) NOT NULL,
  `x` double NOT NULL,
  `y` double NOT NULL,
  `z` double NOT NULL,
  `precision_x` float NOT NULL,
  `precision_y` float NOT NULL,
  `precision_z` float NOT NULL,
  PRIMARY KEY (`ID`,`code`)
) ENGINE=InnoDB AUTO_INCREMENT=4 DEFAULT CHARSET=utf8;
/*!40101 SET character_set_client = @saved_cs_client */;
--
-- Table structure for table `users`
--
DROP TABLE IF EXISTS `users`;
/*!40101 SET @saved_cs_client     = @@character_set_client */;
/*!40101 SET character_set_client = utf8 */;
CREATE TABLE `users` (
  `ID` int(11) NOT NULL AUTO_INCREMENT,
  `name` varchar(20) NOT NULL,
  `surname` varchar(20) NOT NULL,
  `email` varchar(30) NOT NULL,
  `password` varchar(20) NOT NULL,
  `admin` int(1) NOT NULL,
  PRIMARY KEY (`ID`),
  UNIQUE KEY `ID` (`ID`),
  UNIQUE KEY `email` (`email`)
) ENGINE=InnoDB AUTO_INCREMENT=11 DEFAULT CHARSET=utf8;
/*!40101 SET character_set_client = @saved_cs_client */;
/*!40103 SET TIME_ZONE=@OLD_TIME_ZONE */;
```

```
/*!40101 SET SQL_MODE=@OLD_SQL_MODE */;
/*!40014 SET FOREIGN_KEY_CHECKS=@OLD_FOREIGN_KEY_CHECKS */;
/*!40014 SET UNIQUE_CHECKS=@OLD_UNIQUE_CHECKS */;
/*!40101 SET CHARACTER_SET_CLIENT=@OLD_CHARACTER_SET_CLIENT */;
/*!40101 SET CHARACTER_SET_RESULTS=@OLD_CHARACTER_SET_RESULTS */;
/*!40101 SET COLLATION_CONNECTION=@OLD_COLLATION_CONNECTION */;
/*!40111 SET SQL_NOTES=@OLD_SQL_NOTES */;

-- Dump completed on 2015-05-24 15:47:47
```

2. Load geowap.sql using a MySQL interface program like phpMyAdmin or MySQLworkbench.
3. Feed the required data using MySql functions.

Step 7. Changing the user and password for MySQL

1. Read the following information for MySQL-PHP connector function.

   - **$connect=mysqli_connect("YourServerName.com:YourPort","YourUser", "YourPassword","geowapp");**

2. Change the following information in the PHP folder: “YourSeverName.com” by the server URL will be used, “YourPort” by MySQL default port, and “YourUser” and “YourPassword” by the user and password specified in Step 2. This information should be change in the files listed below.

   - bowditch.php
   - compare_leveling_work.php
   - logged_in.php
   - leveling_least_squares.php
   - register.php

Read the following information for MySQL-Python connector function.

- ***cnx = mysql.connector.connect(user='YourUser', password='YourPassword', host='YourSeverName.com', database='geowapp')***

Change the information in the following Python files in the Python folder

- horizontal_accuracy.py
- traverse_to_KML.py

Step 8 configuring the path for the KML files..

1. Set your KML folder address like the next example:

   $kmlpath1 = 'http://atlas.gge.unb.ca/geowapp/KMLS/'.$KML_name_1;

   And, so on with similar variables.

2. Change the text marked in the following files.

   - bowditch.php

- vertical_accuracy.php
- horizontal_accuracy.php

Step 9. Access the web application using http://YourServerName.com/geowap/index.php and play with it.

1.17 Appendix 2: User Review survey sheet.

GEOWAPP survey sheet

Which tool did you used?

1	Check out your traverse
2	Check out your leveling
3	Least square tool
4	Horizontal checking accuracy
5	Vertical checking accuracy

Section I. Information provided by GEOWAPP

How do you feel about the numerical information displayed in the application?

1	I do not think that it helps
2	It may help a new student, but it needs to display different information.
3	I definitely find it useful

If you answered item 2 of last question please tell me which information you would find useful.

In terms of self-evaluation, would you feel more comfortable if you get this information when you are in the field making measurement

1	No, I would feel the same
2	Probably, I am not really sure about it
3	I definitely would feel more comfortable if I can review the measurement while I am in the field.

Section II. Geospatial web tool part (if you used any of the leveling tools please past to the next section)

If you were a new student, would it help to visualize more effectively your work on the field?

1	Not at all
2	I probably would be confused as well
3	Yes, It would help me to visualized my work

4	It definitely will give me the concept of what I am doing in the field.

If you were looking to find where a blunder (gross error or a mistake) happened, this tool will help to so more effectively.

1	Not at all
2	I probably wouldn't know where the blunder is even if I see it.
3	Yes, it would help me to know the area where the blunder occurred
4	It definitely would help me to identify any gross error more easily.

Section III. About the concept.

What are your feelings about the concept of a Geospatial Web Application for enhancing survey labs?

1	Bad idea, not very useful
2	Interesting but not applicable
3	Really interesting and technologically advanced
4	Useful, interesting and very technologically advanced

Section IV. Your comments.

If you have comments or ideas about the tool or suggested changes/improvement, please write them down.

1.18 User Guide

1.18.1 Register

1. Click on register
2. Input your information (see Figure Tut 1)

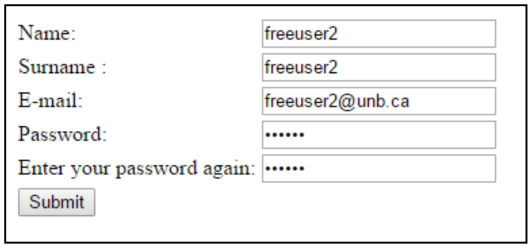

Figure Tut 1: the register window.

** note: all registered users are by default student. If an instructor account is needed should be modified with an SQL statement: ***UPDATE users SET admin = 1 WHERE `email`= "freeuser2@unb.ca"***;

Sign in:

1. Add your email and password.
2. Press the Sign in button. (see Figure Tut 2)

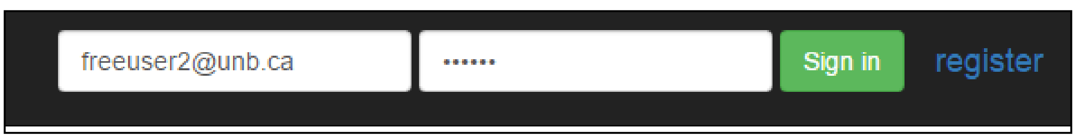

Figure Tut 2: Sign in window.

1.18.2 Traversing comparator:

1. Click on **traversing**

2. Click on **check out traversing**
3. Define the traverse type:
    a. Starts in point A and Finishes in point B.
    b. Start and finishes in point A in “Insert traverse type”
4. Define de number of observation. This option requires an integer number.
5. Click Submit
6. Insert angles, minutes, seconds, and distances.
7. Insert the code of the control points (see Step 3).
    a. For option 3.a, type the code the initial station (ex. tst1)
    b. For option 3.b, type the code of the initial and the final station (ex. tst1. tst2).
8. To show the map click in display traverse.
9. Check the checkboxes non-adjusted traverse and adjusted traverse to display the traverse polygons.

Example: option 3.a, number observations = 7, initial station code = tst1:

Please insert the following data

Table Tut 1: Traversing data (units: meters).

from	To	deg	min	seg	Dist
1	3	353	41	17	220.56
3	4	59	4	50	192.457
4	2	98	7	5	184.7
2	5	181	1	3	208.919
5	6	222	36	11	157.052
6	7	296	54	33	156.841
7	1	242	36	23	82.914

Point A **tst1**

** Point A has real coordinates in NB-stereographic projection and it is stored in the database.

1.18.3 Leveling Comparator:

1. Click Leveling
2. Click in **check out your leveling**
3. Insert the number of forward turning point and the backwards turning points:
    a. "Define the number of turning points for forward run"
    b. "Define the number of turning points for return run"
4. Press submit
5. Insert the Benchmark codes: initial and final station (ex. BMMIL, BMOAK).
6. Insert the backsight readings, the forwardsight readings, and the distance between the rod locations**.

    ** The distance between rod locations is optional. If no value is included, the program assumed 1 km as the total levelling length.

    Example:

    a. BM1 = BMMIL
    b. BM2= BMOAK

Insert the following data:

Table Tut 2: Leveling Data (units: meters).

St	BS(+)	FS(-)
BMMIL	0.405	
TP1	0.067	2.551
TP2	0.293	2.411
TP3	0.140	3.572
BMOAK	3.642	2.655
TP4	3.825	0.796
TP5	3.892	0.207
BMMILL		0.064

1.18.4 Least squares leveling tool:

1. Click on **Leveling**
2. Click on **Least squares tool**
3. Define the number of observation equation involved in the least squares adjustment. (this number depends on the number on the number of repeated observation).
4. Define the number of known benchmarks.
5. Add the weight constant. If unknown, set it to one (1).
6. Insert the data and submit.

Example:

a. Set the number of observation Eqs. involved in the least squares computation to five (5).

b. Set the number of known benchmarks to four (4).

c. Add the following data.

Table Tut 3: Least squares data (units: meters).

From	To	Dist(km)	Lev. Diff.(m)
BM1	A	2	10.997
BM2	A	2	-9.169
A	B	0.5	3.532
BM3	B	1	4.858
BM4	B	1	-2.202
1	Bench mark code		BM1
2	Bench mark code		BM2
3	Bench mark code		BM3
4	Bench mark code		BM4
Weight Constant		1	

1.18.5 Proximity Comparator:

1. Click on **Horizontal Checking**
2. Click on **overall accuracy**
3. In **File**, upload the csv file formatted like (ID,X,Y,code) (see Figure Tut 3).

```
ID,X,Y,code
1,2488884.0185,7438772.7883,BL
5,2488873.3142,7438754.6521,BL
24,2488913.0012,7438731.2904,BL
25,2488917.9676,7438728.8061,BL
```

Figure Tut. 3: csv format for the horizontal checking comparison (units: meters).

4. Select the sample name set by the instructor.
5. Then S**ubmit**.
6. Click on **display accuracy polygons**

7. Check the checkbox **Tested point**. These tested points are the sample stored in the application.
8. Check the **checkbox your survey points**: This are the points you uploaded.
9. Analyze the information: a red pinpoint means that no point was found within the tolerance; a green pinpoint means that a point was found within the tolerance)
10. Click on **Download report**
11. Look at the report. The report shows from the Id's of the points and the distance within points. At the end of this report, a RMS value is given.

Example:

- Download a horizontal sample located in the main window.
- Upload the downloaded file (make sure that the file name does not have a special character like: "(), -, *, /, etc. ").
- Choose sample_prox_1.csv in sample name.
- Check the results.
- Submit.

Vertical Comparator:

1. Click on **Vertical Checking**
2. Click on **Vertical Accuracy**
3. In **File**, Upload the file for processing. This csv file formatted like (ID,X,Y,Z) (see Figure Tut 4).

```
ID;Y;X;Z
1;7438628.399;2488888.073;46.34
2;7438671.222;2488819.478;46.222
3;7438699.767;2488827.246;41.68
4;7438708.231;2488880.159;37.763
```

Figure Tut 4: csv format for vertical checking (units: meters). GEOWAPP accepts a coma (,) or semicolon (;) as delimiters.

4. Select **Sample name**.
5. Input accuracy required in meters.
6. Select the number of points used in the triangulation (3, 4, or 5).
7. Click on **Submit**
8. Click on **display accuracy polygons**
9. Analyze the information(look for the accuracy polygons)
    a. Accuracy Polygon: this KML file shows the areas that are not well represented by students' survey.
    b. Tested points: this KML file shows which of students' points falls within the tolerance.
    c. Circular Residual: this KML file shows the residual of the students' points testing (previous item).
    d. Sample point: this KML shows the sample points used in the interpolation and test of students' points.
10. Click on **Download Accuracy Polygon Interpolation report**. This report is the product of testing the areas and contains the interpolated point (# sample), the point used for interpolation (PT1,PT2,…, PT5), the known Z coordinate of the interpolated point (Zkn), the interpolated Z coordinate (Zint), and the residuals (res).
11. Click on **Download Point Validation Interpolation**. . This report is the product of testing the students' points and contains the interpolated point (# sample), the point used for interpolation (PT1,PT2,…, PT5), the known Z coordinate of the interpolated point (Zkn), the interpolated Z coordinate (Zint), and the residuals (res).

Example.

- Download a vertical sample located in the main window.
- Upload the downloaded file (make sure that the file name does not have a special character like: “(), -, *, /, etc. ”).
- Choose DATASAMPLE.csv in sample name.
- Input the tolerance value (m) for testing the areas in the accuracy required textbox.
- Select the number of points for interpolation.
- Submit.

Curriculum Vitae

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