SaGISC: A Geo-Collaborative System

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Abstract. The production of geological mapping by conventional processes is a complex work of data gathering and integration, along with expert and team analysis. This process is very time consuming, since it implies several expeditions to the study location. In the organization studied by this paper, this process can take several years to be completed. The objective of this project is to build a remote collaborative system that supports information sharing by the teams that participate in geological data gathering. The developed system integrates several tools for information sharing and geological/topographical data referencing, as well as support to group discussion and decision. The integration of these tools makes up a geo-collaborative system. The development of this system was done in the context of the Portuguese Geological and Mining Institute (IGM). The evaluation of the prototype by 30 experts from IGM revealed that the proposed goals were accomplished: the system was considered better than the conventional approach.

1 Introduction

The process of gathering geological data has two components of extreme importance: office and fieldwork. The first stage of this process takes place in the office, searching for preliminary information about the target area. This preliminary information includes bibliography, notes from previous field works, charts, geochemical results, geophysical results, etc.

A second stage occurs in the field, with geological data gathering. Field work varies significantly according to the intended goals. For instance, one may have to carry out a detailed analysis, using a 1/5.000 scale, for a geo-technical and hydrological study, or a more regional study, using 1/50.000 or higher scales.

After this stage and back in the office, the field technician, together with a geological coordinator and/or experts from other areas, review all the gathered data and search for the best method to integrate the information in a meaningful way. This is similar to setting together the pieces of a jigsaw puzzle.

Finally, the geological coordinator goes to the field to validate and/or review the results and, in case of doubt about any geological element, requests for help from

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specialists in specific areas such as structural geology, paleontology, petrology, sedimentology, etc. This collaboration usually implies one or more visits to the study area, sometimes in remote places with difficult access for any of the experts, including the fact that all this process can be expensive and time consuming (for instance, in the case of IGM, studies in the Azores islands are usually very expensive and time consuming, being scarcely populated and located in the middle of Atlantic).

With this action-research project we tried to design, develop and experiment a prototype of a geo-collaborative system that supports gathering geological data and, at the same time, allows field technicians to exchange information with other specialists on the office. The fundamental idea behind the geo-collaborative system is to economize on the number of visits to the field necessary to analyze dubious situations, or to get second opinions on specific geological elements.

The developed prototype interacts with Geographic Information System (GIS) tools and supports obtaining geo-referenced data such as notes, messages, photos, sketches and sound. The prototype generates an e-book with all the information associated to the points gathered on the field, which represents an electronic substitute of the artifacts traditionally used by the specialists. The prototype centers the collaboration between all experts in this e-book, giving a new dimension to information sharing supported by instant messaging tools like MSN® Messenger.

The development of this prototype followed a user-centered approach, based on the Contextual Design Methodology proposed by [Beyer 98].

This paper is structured in the following way: In the next section we will describe the traditional information gathering process, without any computer support; Next, we will present the design of a geo-collaborative system that will transform this traditional process, identifying the requirements and the new information gathering process; Then, we will give some additional details about the prototype; Finally, we will describe the experiments done with the prototype and present the obtained results from the prototype evaluation carried out by 30 experts from IGM.

2 Traditional Data Gathering in Field Work

The detailed analysis of geo-referencing work on the field, as well as information gathering and decision making tasks necessary to carry out geological mapping, was made with the support from experts of IGM.

Field work begins with the technician trying to locate himself on the chart and on the field, using a compass or GPS and any conspicuous points that may be referenced on the chart. Next, the technician checks the geomorphology of the zone to see if any spot heights could give her some hints of the geology of the zone. For instance, spot heights can give an indication of hard formations, e.g. Quartzites. Conversely, a water line could hint a zone of geological weakness or fault. From this stage, the field technician annotates the chart (not exactly the chart, as will be described later) and geo-references data in a field book with everything relevant that she observes.

In Figure 1 we present an example of a page of the field book, which is filled up with several notes, descriptions, doubts and sketches.

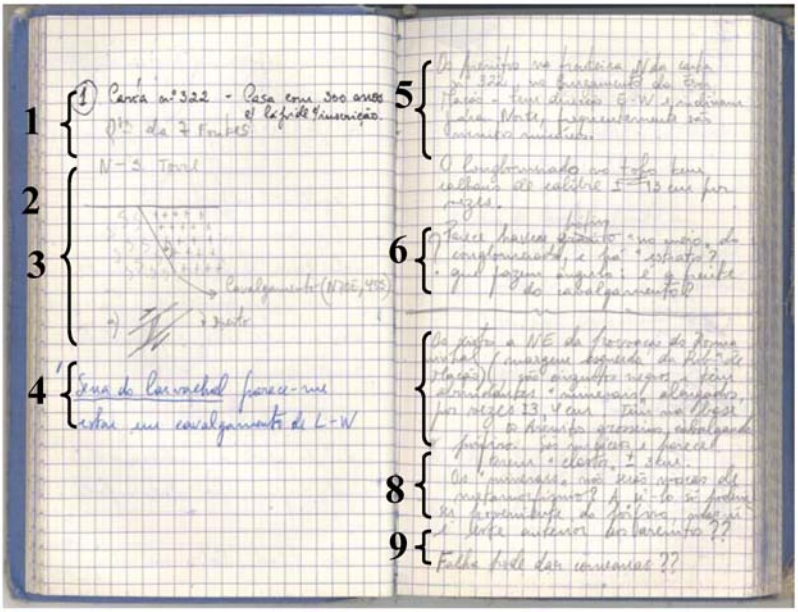

Fig. 1. The field book

As can be seen on the transcription below, the localization, geological descriptions, sketches and doubts that arise on the technician's head are important to characterize field work:

1) Importance of localization – "Map nr. 322 – 300 year old house"
2) Sketch of trust fault and orientation
3) Doubt – "Carvalhal hill seams to be in trust fault from East-West"
4) Description with localization – "The sandstone in the border of map nr. 322, in the intersection of road Mação [located approximately 150Km North of Lisbon] have East-West direction and dip towards North, are frequently Micaceous"
5) Interrogated Description – "Porphyry seem to exist in the middle of conglomerate. Are there any strata? Which have an angle: is it Pyrite in the trust fault?"
6) Doubts with geo-referencing
7) Doubts – "Are the minerals metamorphism derived? Being so, they have their origins in Porphyry, but are not they previous to sandstones?"
8) Doubt – "Fault could give Hornfels?"

In the field notes transcribed above there are several doubts that might disappear with a second visit to the study area. This is the case of point 3). The clarification of this doubt could give a whole new geological interpretation of the area. Another doubt is point 7) where the field technician is not sure if the minerals there are metamorphism-derived. And in that case, there is another doubt with a structural context: "but is not Porphyry previous to sandstones?" This kind of a doubt could be raised or answered afterwards by the coordinator geologist or by the mineralogist/petrologist. If the doubt persists, the technician may have to consult another expert, e.g., a structural geologist, who may have to visit the study area or alternatively request further measurements from the field technician.

Fig. 2. The technician taking measures with the compass

Fig. 3. The technician tracing on the transparent paper overlaying the chart

While the technician goes through the territory, she measures with the compass the attitude and inclination of the geological formations (Figure 2). This action can help reviewing the geology of the field, as the same values for inclination can indicate the same formation.

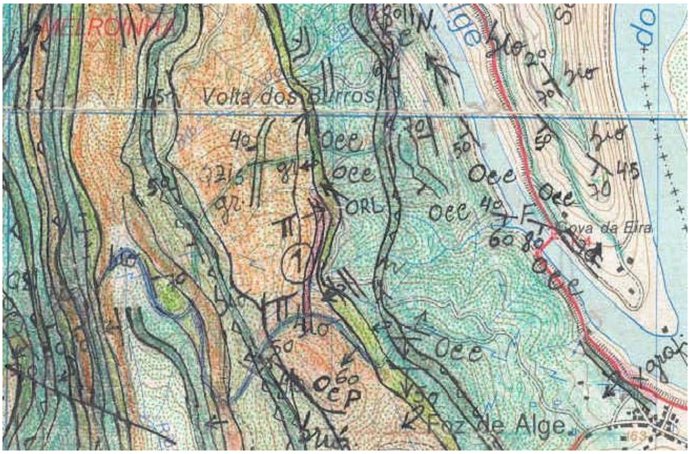

Fig. 4. Example of the notes taken on the transparent overlay

The technician preserves this information by tracing on a transparent paper which is overlaying the 1/25.000 chart (Figures 3 and 4). In order to help identifying the geology of the territory, for example Silurian or Ordovician, the technician also uses the geologist's hammer. It is important to check not only rock fragments but the sound produced by the hammer striking the rock. For instance, in the concrete field work illustrated in Figures 1-4, the Quartzites produced an acute sound, almost metallic.

2.1 Collaboration in Field Work

Usually, considering a traditional field work, there is a team on the field, which may be composed by one or more elements, who observe, analyze and interpret the geology and data in situ, gather information and reference that information on the overlay paper and field book. The field team reports to the IGM team (the members of the field team may also be members of the IGM team), while promoting discussion, reviewing and consolidating field information and, whenever it is necessary, obtaining clarifications and explanations from the members of the IGM team.

The IGM team is usually composed by a geological coordinator, responsible for a particular geological mapping project, and experts in geology and other related fields, like hydrogeology, geophysics, etc. This team, having overall responsible for the project, observes, analyses, and interprets the geological data obtained on the field and at the IGM itself. The team is also responsible for resolving doubts, discussing results and guiding future activities from the field team. Whenever it is necessary, members of the IGM team go to the field in order to revise, clarify and consolidate geological information. The collaboration between these two teams is illustrated in Figure 5.

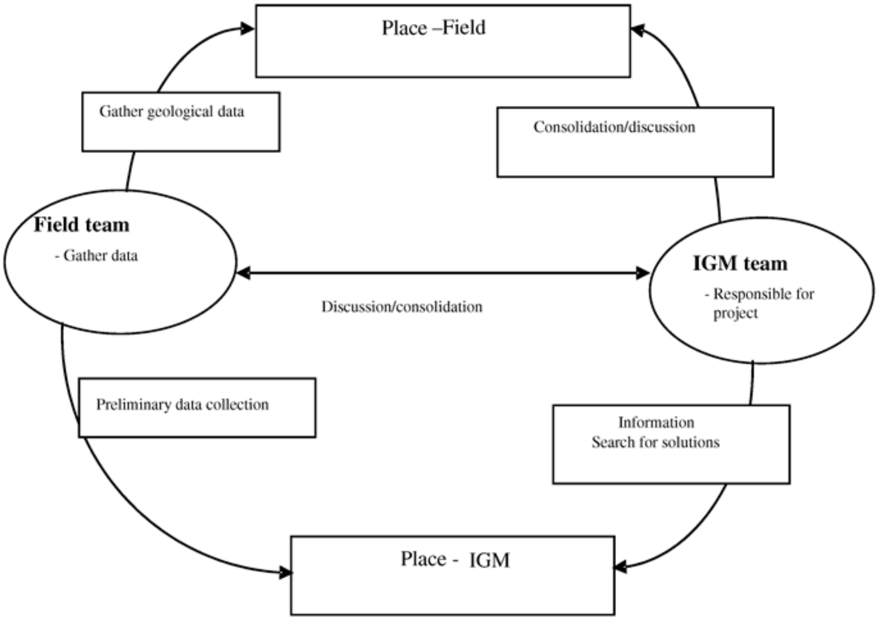

Fig. 5. Collaboration between field and IGM teams

3 Collaborative System Design

As it can be seen in the previous description, the gathering of geological data and execution of geological mapping have to be made both in the field and the office, requiring collaboration between teams and a high degree of expertise in geology. The proposed system should allow high mobility to the people in the field and also preserve as much as possible the freedom to use their hands for tasks such as analyzing the geology of the territory, using the hammer, compass, GPS, etc.

The collaboration support to field and IGM teams should afford some flexibility getting in contact with the IGM teams, since the fundamental purpose of the system is to avoid the need to get back to the field. On the other hand, these contacts should not be very disruptive to the work of the IGM teams, since the contacts are varied and occasional. For these two reasons, we adopted an instant messaging mechanism like MSN® Messenger. Such a mechanism is well-aligned with the current workplace at IGM, and affords the immediacy of contacts from field teams. In that way, the teams will not hesitate to discuss questions, doubts or different opinions [4]. Furthermore, the approach affords two alternative work arrangements for IGM teams: either scattered among their usual workplaces, or grouped together on a team room.

To simplify the establishment of contacts from the IGM to the field teams an audible warning is implemented.

Instant communication between the field and IGM teams is related to geo-referenced information available in geologic and topographic charts. Fortunately, this shared context does not require exchanging charts between the two teams while working in the field (which would impose significant requirements to the communications infrastructure). This shared context is developed during the planning stage, where relevant information is identified and disseminated to both teams. The system must however grant the coherence of the references to these charts.

We also noted on our observations of field work that the field book assumes a very significant role, being the place for inserting notes related with any information gathered in the field, including doubts, sketches and drawings. Based on this observation we decided that the support to collaboration should be centered on a digital artifact which could reproduce the actual field book. We designate this artifact as a field e-book. The field e-book shares information between the field and IGM teams, although on demand only, in order to lower the requirements to the communications infrastructure. The information introduced in the field e-book is geo-referenced, letting the users search for available information about a specific point, at any moment and either locally or remotely. This feature represents an extension to the traditional field book.

The types of data that can be introduced in the e-book are: (1) location coordinates; (2) notes, where geologists write doubts, descriptions and comments; (3) drawings of geological elements; (4) photos; (5) sounds of the geological hammer striking rocks; and (5) messages exchanged between teams related with the specific coordinates.

We previously mentioned that technicians gather information in the field using three main physical artifacts: the field book, the topographic/geological chart and the transparent paper overlaying the topographic map and attached to a backing board. We already mentioned that we substituted the field book with an e-book. Concerning the chart, our solution uses ArcPad® [1], a GIS tool belonging to ArcGIS Mobile Software from ESRI® [3], which is commonly used by IGM. Concerning the transparent overlay, we came to the conclusion that it would not be feasible to implement a computational substitute for this physical artifact (lack of time, money and resources). Thus, such functionality is not developed and the user must rely on a workaround, using a drawing tool not integrated with the topographic/geological chart.

Finally, to connect all the components referred above, we developed a tool designated SAGISc. This tool allows the technician on the field to manipulate the e-book, establishing communications with the IGM team (using MSN® Messenger) and interacting with ArcPad® and the drawing tool. The remaining hardware and software used was: GPS device, digital camera, microphone and sound recorder.

Because there is a low level of control exerted by the system on the collaborative activities, the system usage will work best with technicians that already have good work relationships. An informal but disciplined social environment corresponds to the ideal situation for working with the system.

3.1 Redesigned Collaboration Using SAGISc

In the diagram presented in Figure 6 we illustrate how the field and IGM teams collaborate using SAGISc.

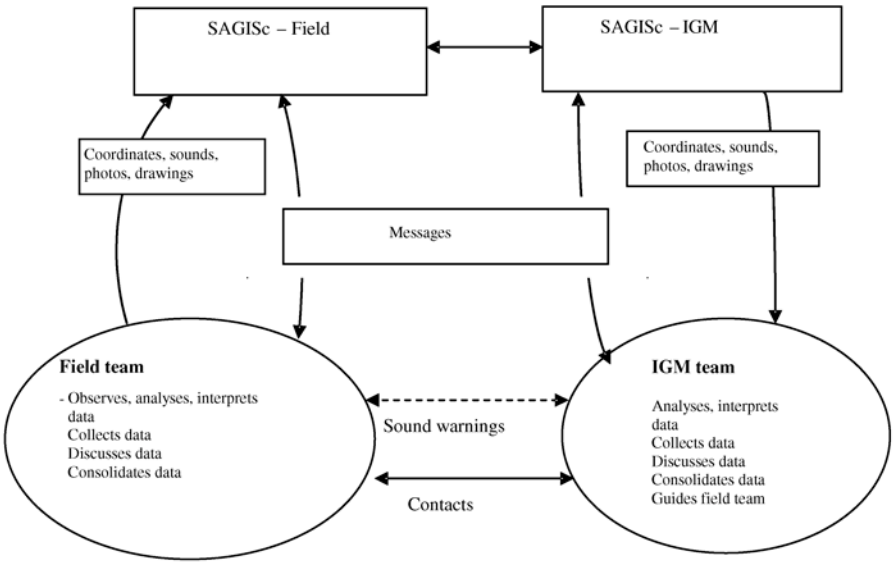

Fig. 6. Collaboration between field and IGM teams using SAGISc

4 Implementation

The SAGISc prototype was developed with the VB.NET® language, basically because it would be adequate for prototyping and easy to integrate with ArcPad®.

Since this a prototype aiming at experts in geo-sciences working on the field, we had particular care with the structural navigation aspect of its development, focusing on simplicity and consistency of use. In Figure 7 we describe the structural navigation structure of SAGISc.

5 Evaluation

After the implementation of the SAGISc prototype, we had it evaluated by users. The evaluation process was done in two successive steps. First, we had a preliminary evaluation with users working in the field with the system. The experiment was done with technicians from IGM, where the field team was composed by a Geologist and the IGM team was composed by three specialists of different areas in Geology. After this preliminary evaluation, we set up a broader but “static” evaluation. Overall, 30 IGM specialists in Geo-sciences participated in the evaluation process.

The preliminary evaluation was carried out in circumstances very close to reality, during which a field team was sent to Oeiras (located approximately 15 Km West of Lisbon) with the goal to verify and discuss the geology of the area with the IGM team that was in the IGM main office. The field team was composed by one geologist with low experience in this kind of work (collecting data in the field), because her spe-

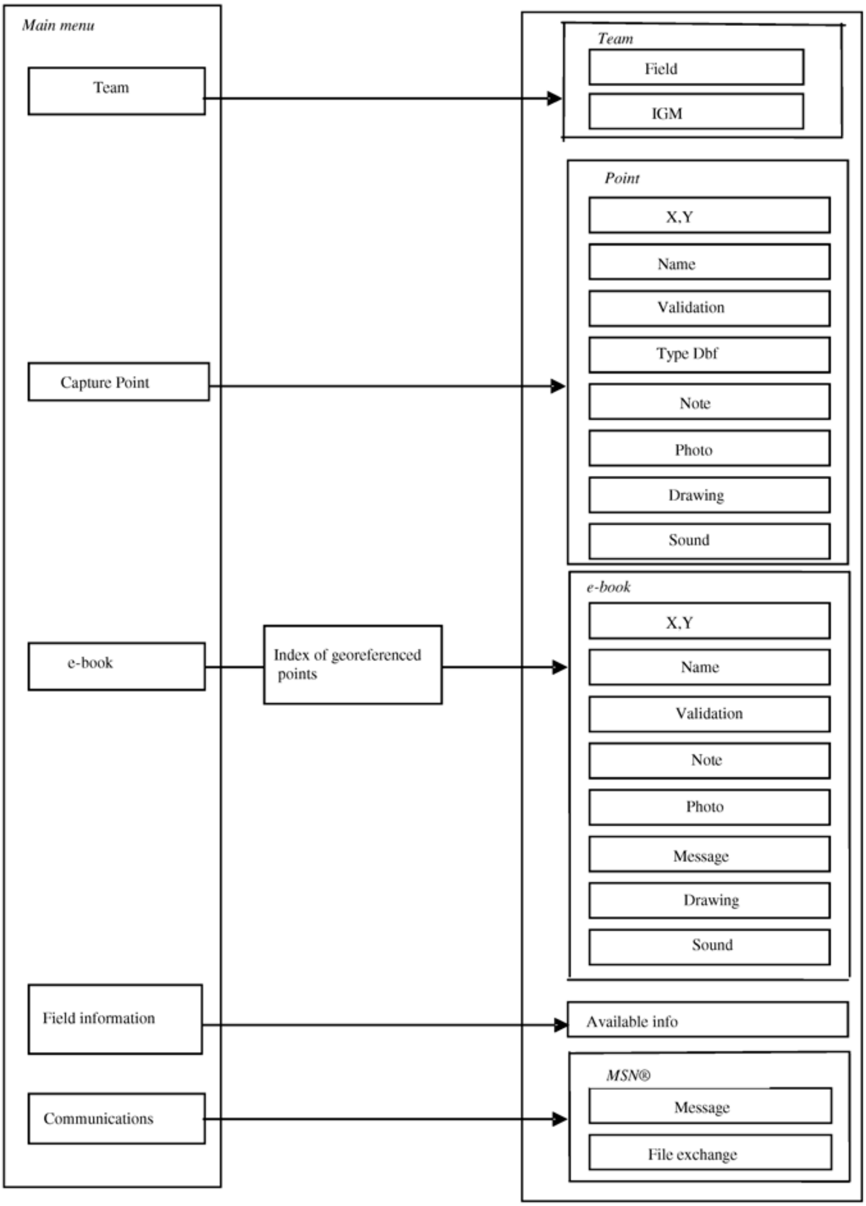

Fig. 7. Structural navigation of SAGISc

cialization area is Micropaleontology. The IGM team was composed by three specialists in the Geo-sciences fields (a geologist, a hydro-geologist and a geological engineer). Both teams were given the necessary hardware and software, and were briefly instructed on the system usage.

The geologist on the field carried the following equipment: a laptop with GPRS card, GPS, compass, geologist's hammer, microphone and digital camera. The software included in the system was: SAGISc, Olympus Camedia®, Notepad®, Freehand®, Sound Recorder® and MSN® Messenger. See Figure 8.

The IGM team had the following artifacts: computer with Internet connection, sounds cards, ArcPad®, MSN® Messenger, SAGISc, scanner and telephone. See Figure 9 for details.

Fig. 8. Element of field team using artifacts (laptop, hammer, compass, GPS, etc.)

Fig. 9. The IGM team working around the e-book at the IGM main office

5.1 Preliminary Evaluation Results

The participants in the preliminary experiment were all individually interviewed in order to identify the system strengths and weaknesses. The obtained results indicate that the system was easy to use and helpful, especially because of the component supporting communication between teams. The expeditious way to locate points and insert information related with these points was also positively considered.

Generally, the system has worked well and met the users' expectations. A few problems arose in communications, because one of the points was on a cliff close to the shore and originated losses in communications. The participants also mentioned that the user validation and file exchange with MSN® Messenger suffered from slow communications.

The portability and, in some situations, the usability of the equipment were also considered negative factors.

In what concerns collaboration, the participants had a very positive experience, especially at the second point where, through the exchange of messages the users were able to identify the type of geology of the area.

5.2 Results from the Broader Evaluation

This evaluation process was carried out by questioning a panel with over 30 specialists in Geo-sciences from IGM. The evaluation involved a detailed demonstration of ArcPad® and SAGISc, and a reproduction of the preliminary experiment, showing photographs, messages exchanged, the produced e-book and how both teams cooperated. After these explanations the participants were requested to fill up an individual questionnaire.

5.2.1 Results

The evaluation focused on the work activities of the panel, experience with IT and experience with field work. We requested an evaluation of the "new system," consisting of three new components: ArcPad®, SAGISc and the combination of both (ArcPad®+SAGISc). We also requested the panel to compare the "new system" with the traditional method of doing field work. We used a Likert [7] classification scale, varying between 1 and 5 (Bad, Low, Average, Good and Very Good).

After an analysis of the questionnaires, the following points were highlighted:

a) About the experience with IT and field work

As can be seen in Figure 10, the distribution of the level of experience with computers is median, biased to the right, with this distribution: 50% of the respondents considered themselves as Average and 30% Good. Statistical values: Mean = 3.3; Standard Deviation = 0.9.

Concerning the experience with field work, it can be seen that the panel is more at ease, since 63% of the participants consider themselves Good and 27% Very Good. Statistical values: Mean = 3.8; Standard Deviation = 1.1.

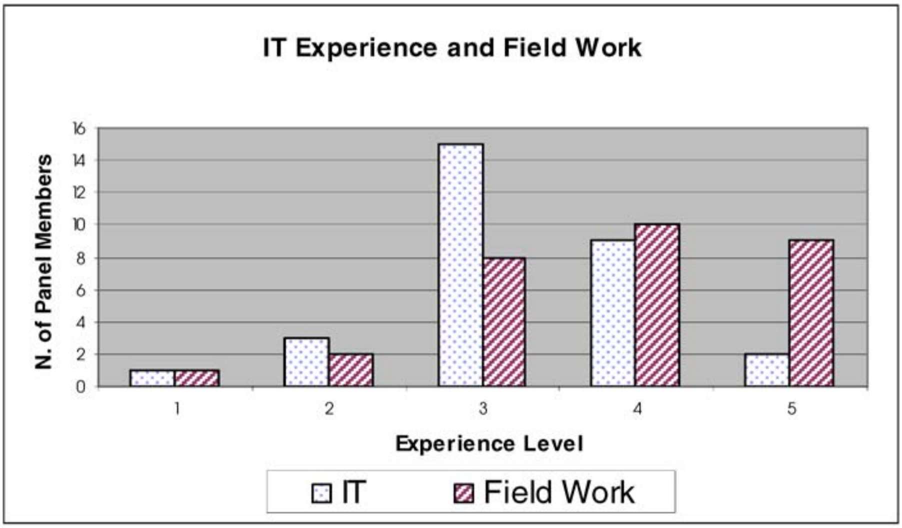

Fig. 10. Experience with IT and field work

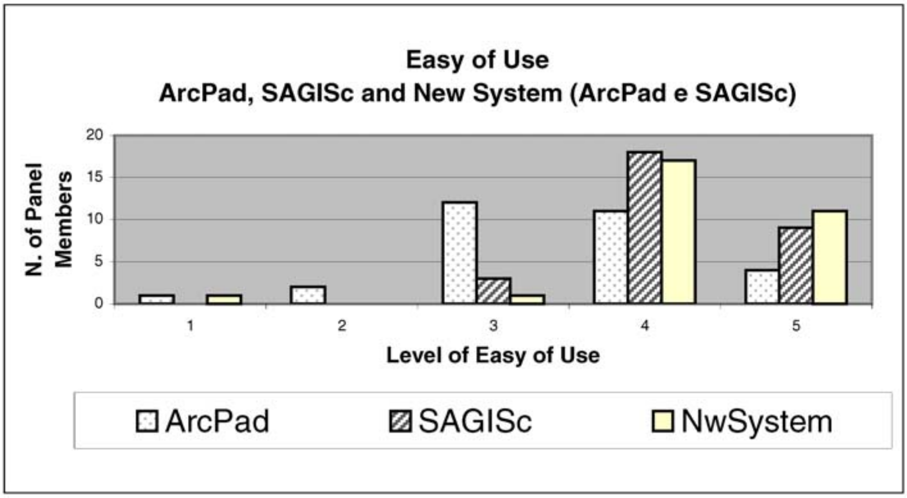

Fig. 11. Ease of use

b) Evaluation of the "new system"– ease of use

Generally the tools under evaluation were all considered to be easy to use (Figure 11), with a large number of answers in level 4 – 60% panel members rated SAGISc as easy to use, while 57% had the same appreciation about ArcPad®+SAGISc (NwSystem). Statistical values: ArcPad®: Mean = 3.5; Standard Deviation = 0.9. SAGISc: Mean = 4.2; Standard Deviation = 0.6. ArcPad®+SAGISc: Mean = 4.2; Standard Deviation = 0.8.

c) Comparison of methods – Traditional field work vs. “new system”

We used the following questions to compare both approaches:

In relation to a traditional geological data gathering, this system:
a) Will make your work easier?
b) Will make the work developed by IGM easier?
c) Will make the exchange of opinion easier?
d) Is it quicker to get a second opinion?
e) Is there and increase in observation/problem analysis abilities?

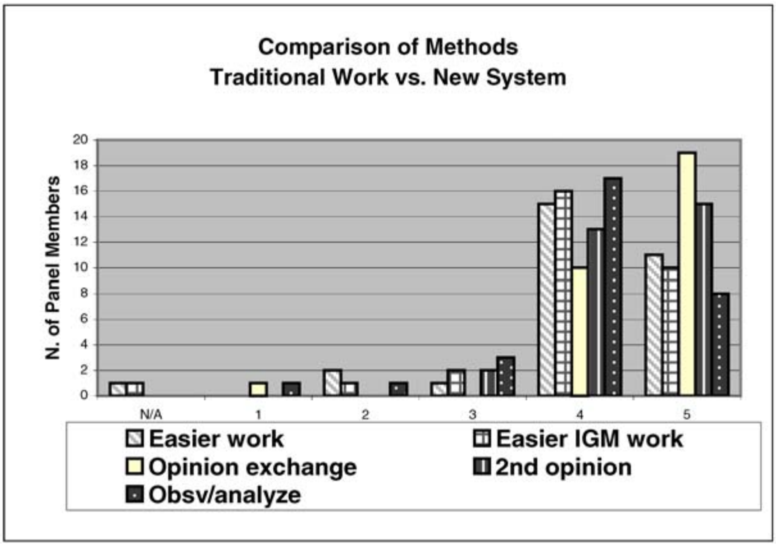

Fig. 12. Traditional field work vs. “new system”

In general, the panel considered the “new system” Good or Very Good (Figure 12). However, 63% and 50% panel members evaluated the “new system” as, respectively, Very Good for easing the exchange of opinions and speed at obtaining second opinions, respectively. As a side note, one respondent did not answer (N/A) the first and second questions. Statistical values: Easier work: Mean = 4.2; Standard Deviation = 0.8. Easier IGM work: Average = 4.2; Standard deviation = 0.7. Opinions exchange: Average = 4.5; Standard Deviation = 0.8. 2nd opinion: Mean = 4.4; Standard Deviation = 0.6. Obsv/analyze: Mean = 4; Standard Deviation = 0.9.

d) Evaluation of components of the “new system”

In this question the panel was asked to rank the “new system” components from the worst to the best. 57% panel members pointed out that the ergonomic aspects of the equipment were the worst component of the system (Figure 13). We should note that this answer was based only on the equipment presented to the panel: a laptop plus several peripherals. 43% respondents preferred the communications between teams and gave the maximum classification to that component. The “new system” had an evaluation of Average and Good from 33% and 30% respondents, respectively. The SAGISc was evaluated as Average and Good by 30% and 27% of the respondents, respectively. 37% panel members considered ArcPad® below SAGISc and the “new system.”

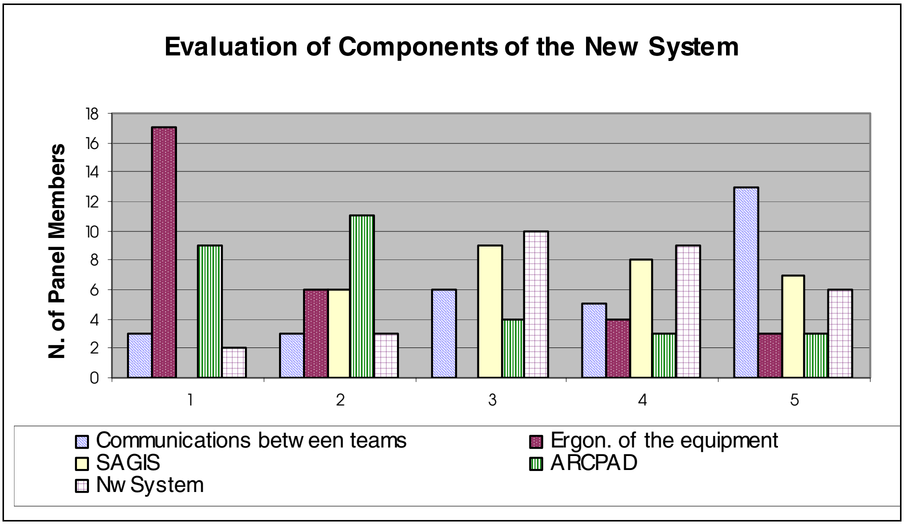

Fig. 13. Evaluation of components of the “new system”

5.2.2 Analysis and Conclusions from Evaluation

The results obtained from the panel indicate an easier usage of the components that integrate the collaborative system, particularly SAGISc, which was considered the easiest to use by 60% of the panel members.

Comparing with the traditional method, the “new system” was considered to be a great development; facilitating data exchange (63% of the respondents rated Very Good) and access to a second opinion (50% rated Very Good).

7% of the respondents considered that the “new system” is negative (Low) in facilitating field work. Nevertheless, about 50% of the respondents considered that field and office work will be facilitated by this system (Good). The Mean value for making the work easier is 4.2 and Standard Deviation is 0.8; concerning the work done in IGM being improved, the Mean and Standard Deviation are respectively 4.2 and 0.7.

The increased capacity of observation/analysis is considered positive by 57% of the respondents (the Mean is 4 and the Standard Deviation is 0.9). 43% of the respondents pointed out that the communications component is the best aspect of the “new system.” The evaluation of SAGISc and “new system” revealed very similar results, since the respondents seem to had some difficulties in distinguishing one from the other.

The worst component of the "new system" was ergonomics (57% of the answers), which is coincident with the results obtained in the preliminary evaluation.

This evaluation also revealed that ArcPad® did not achieve a good acceptance. It was considered the worst component of the system by 30% of the respondents (Bad), while 37% rated it Low.

In general, the "new system" had a good acceptance and was considered to be very useful to the work developed by Geologists; although more ergonomic equipment is required to be properly used in the field. The communications also need to be improved both in performance and reliability.

6 Related Work

The research in geo-collaboration is very recent and there are few papers published on this subject in the scientific literature. Essentially, work in this area can be separated in two different categories: one centered in technology and another in human geo-collaboration.

In the first category we should account for systems like Open GIS [5] and COPA [13] that study different ways to integrate scattered information with geo-referenced information. These systems do not directly support geo-collaboration but explore structured solutions that afford such functionality.

Still in the first category, we should highlight the efforts in the development of synthetic environments for geographic visualization (geo-visualization) [8; 9]. In this perspective, geo-collaboration refers to the support of information exploration by various users inside synthetic environments. In this case, fieldwork is not considered.

In the second category, related with human geo-collaboration, we find two projects that are currently being developed [11; 12], both concerned with the problem of interacting with geo-referenced information, in digital format and during field work. These projects study the integration of contextual information (photos, etc.) with geo-referenced information, and mention that they are studying several ways to navigate through information gathered on the field. Concerning these projects, only preliminary information is currently provided, without any experimental results.

Still in the second category, [6] studies the impact of geo-collaboration in work practices. Contrary to the work reported in this paper, the goal was centered in the access to remote databases. [10] supports the coordination between geo-collaborators, developing an integration system between GIS, workflow systems and other unstructured tools (meeting support, argumentation and discussion forums). Once again, fieldwork is not discussed.

In summary, we consider that the project described in this paper is about a subject that is not well studied yet: the human aspects of geo-collaboration, in a decision-making environment supporting fieldwork. In this context, we identified the main design issues that should be considered, leading to the development of geo-collaborative artifacts. And we also presented the results on usage of such artifacts, as well as their perceived utility for future users.

7 Conclusions and Future Work

In this action-research project we analyzed the process actually being used by IGM to gather geological data and produce geological cartography. We identified a problem in this process, basically that it takes a long period of time to do it. We studied the possibility to develop a collaborative system with the objective of reducing process time and costs.

The followed approach used several concepts from the Contextual Design methodology [2], which fundamentally focus on the need to understand work processes through contextual inquiry and, from there, derive system design.

With this objective we accompanied IGM field technicians doing geological data gathering. After these observations, we proceed to the construction of descriptive models of work processes and specification of a collaborative system for geological data gathering. The obtained system integrates several tools, from which we would like to highlight two: SAGISc and ArcPad®. The first tool was developed by this project and the second is a commercial GIS tool.

The functionality of SAGISc is centered in the support to a digital artifact that emerged in the contextual inquiry phase: the field book, an artifact where the technician gathers several types of data, related to geological work. The developed prototype allows sharing information on this field book and collaboration between remote and local work teams.

The proposed system was evaluated by specialists in Geo-sciences. According to the obtained results, the collaboration component is the most positive one, the reason being the possibility of decreasing the duration of geological data gathering. On the opposite, the most negative factor concerns communication problems (performance and coverage of GPRS), as well as ergonomic problems (because there are a lot of cables, weight and volume of laptop). The SAGISc tool was considered to be easily understood and usable.

Concerning future work, the system architecture will be modified for Internet usage, where the teams will be able to work over the Web. This development will facilitate the work of Geo-science specialists and will support the simultaneous collaboration of several field teams (currently only one is supported).

The participants in the evaluation process made several suggestions, which are appropriate for future work:

- Allow a geo-referenced point to have more than one associated photo and drawing;
- Include an ortophotomap field in the e-book;
- Include a date field in the e-book;
- Create a library of symbols to use over photos and/or ortophotomap;
- Remove the sound field, since some specialists have the opinion that the sound is too distorted and does not allow to precisely understand the type of geology being studied.

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