A Context-Aware Web Content Generator Based on Personal Tracking

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Abstract Context-awareness has been successfully included in the mobile phone applications due mainly to the presence of numerous sensors and the access to several communication networks. Therefore, we present a Context-Aware Web Content Generator Based on Personal Tracking, which uses the user context information obtained by mobile devices to generate content for a large number of web applications. While registering the trajectory followed by the mobile device, it allows users to create multimedia documents (e.g. photo, audio, video), which are connected to an enriched description of the user context (e.g. weather, location, date). Finally, all this data and documents are combined to produce a new content, which is published on the Web. We also show results of tests performed in a real scenario and describe our strategy to avoid battery overconsumption and memory overflow in mobile phones. Moreover, a user evaluation is presented in order to measure the system performance, in terms of precision and system overall usability.

1 Introduction

Mobile phones, nowadays, are not simple call-making devices anymore. They have already become real information centers. With all the embedded features like GPS, accelerometer, Internet connection, digital camera, among others, a user easily creates and publishes personal multimedia content. For instance, any user can quickly take a picture and put it in his/her web-based photo album. In addition, multimedia content can be enriched and organized with context information collected by smartphones, such as date, geographical position and current weather.

There are several applications that use context information to enrich and organize multimedia documents. This information might be proximity of people or objects in the photo, current temperature, date, etc. This type of metadata can

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be obtained from sensors of mobile devices or from the web. With this information associated, context-aware applications can better organize the multimedia, providing user-friendly visualization of the content, and suggesting annotations for document indexation[1][2][3].

In this paper, we go a step forward proposing the use of context information to generate new multimedia content. First of all, the user trajectory is registered by using the GPS sensor of the device. While registering the trajectory, the user can produce multimedia documents, such as: photos, audio or video. Likewise, context information can be associated to each multimedia created, as geographic position, date, and temperature. These data will be easily shared to the Internet, presented as a microblog, for example. In short, our system works in three steps: i) collecting context and user-added data; ii) processing and organizing them; iii) publishing the composed content on a web-based application (e.g., blogs/microblogs, web albums).

It is also important to mention that context-aware systems have some dependencies that may not be satisfied in some situations. The Internet connection, for example, can be limited or even not available at certain moments. Another problem is related to the mobile device battery. For example, all these features (GPS, Bluetooth, Internet access, etc.) are necessary to the context data acquisition, but they spend too much electric power. In order to minimize these dependencies, we propose some design decisions that have impact in trajectory and context gathering mechanisms.

In the interest of evaluate the system usability and the performance of our gathering mechanisms, we apply it in a challenging scenario. It was used by three of the crewmembers of a boat as a digital logbook. The system registered the boat trajectory, allowed the insertion of photos, suggested annotations using context information and published the content in the blog of the project ZeroCO2[3].

The organization of this paper is presented as follows. Section 2 presents related works and introduces an overview about context-awareness. Section 3 presents our proposed system. Section 4 discusses a case study of our system tested in a real situation. Section 5 presents results of the system performance and user evaluation. Finally, Section 6 concludes this work and gives some perspectives.

2 Context-awareness is more than system adaptation

Several research areas use the notion of context with distinct meanings.

In the field of information systems, the concept of context refers primarily to the user status and the surrounding environment at the moment he/she is accessing a system. Frequently, the knowledge of the user location is a prerequisite for the success of this kind of system. According to Dey *et al.* [4], the context is constructed from all information elements that can be used to characterize the situation of an entity. An entity is defined as any person, place or thing

[3] www.zeroco2sailing.com/blog/

(including users and the own applications) considered relevant to the interaction between the user and the application. Consequently, the term "context-aware" is associated with systems that guide their behavior according to their context of use. Most authors in this field consider context awareness as the ability to perceive the situation of the user in several aspects, and adapt the system behavior accordingly [5].

On the other hand, in the multimedia domain, the notion of context, and mainly, its exploitation is slightly different. Context-awareness is more than simple adaptation mechanisms. This distinction is studied in some works, such as Naaman et al. [6], which presented the behavior of users to organize and find photos. In fact, most of the information referred by people about their image memories consists of aspects related to their context at the moment the photo is taken (when, where, with who, etc.). These authors argue that the information about the context creation of a photo facilitates the search of a specific photo in a set of multimedia documents.

The popularization of mobile devices equipped with location sensors and GIS (Geographical Information Systems) have provided the technology and data necessary to develop multimedia systems able to gather the desired context information. Nowadays, we can categorize these context-aware multimedia systems in three groups: multimedia organization and annotation tools; multimedia sharing systems; and context sharing systems.

2.1 Multimedia organization and annotation tools

Following the aforementioned concepts in Naaman *et al.* [6], some research projects and commercial applications propose automatic photo annotation by using context metadata. In fact, nowadays, the use of photo geotagging is not unusual for mobile users since most of the smartphones contain geotagging applications. For example, in Kennedy *et al.* [7], the authors identified local markers from 110,000 Flickr images of the San Francisco Bay Area. Most of the photos were taken from mobile phones and were georeferenced. Hence, image data with views that best represent a marker according to visual similarity were retrieved by means of a marker or location search.

Research projects, such as PhotoGeo [3], PhotoCopain [8], MediAssist [2], and PhotoMap [9] gather a larger set of contextual metadata, which includes user location, identity of nearby objects and people, date, season and temperature. They exploit these contextual metadata for photo organization, publication and visualization. For instance, PhotoMap provides automatic annotation about spatial, temporal and social contexts of a photo (i.e., where, when, and who was nearby). PhotoMap also offers a Web interface for spatial and temporal navigation in photo collections. The system exploits spatial Web 2.0 services to show where a user took the photos and the itinerary followed when taking them.

2.2 Multimedia sharing systems

The modern capabilities of mobile devices and the success of Web 2.0 sites stimulate a new kind of multimedia phenomenon: the create-to-share behavior [10]. Mobile users create multimedia using their devices and with the purpose of sharing the information almost instantly.

Some context-aware systems try to exploit context metadata to increase this experience of multimedia sharing [10] [11]. For instance, Zonetag projects [10] use the position information to suggest the photo annotation before sharing it. Other approaches aim to refine the multimedia content taking into account the user context. For example, the Aware project [11] replaces the MMS application in Nokia mobile phones by a context-aware application, which adds automatically the position information to each MMS sent by the user, such as an address derived from the combination of a GSM Cell-ID and an address database.

2.3 Context sharing systems

A large number of messages shared on social networks, such as FourSquare and Twitter microblogs, refers to the information of user context. Hence, this information can be derived automatically by mobile phones equipped with sensors [12] and published on these Web sites. For instance, ContextWatcher [13] is a mobile application to capture and share the most common context information. The main objective is to acquire and describe accurately the current status of the user. The context information of a user is composed of position (e.g., geographic coordinates, altitude and address), speed, humor, heartbeats and weather. All this information is combined and published over a map-based site that shows the current context of all users.

Other approaches, such as Melog [14] and SnapToTell [15], propose the generation of more complex multimedia documents from a set of pictures created by users and the context information associated to them. For instance, Melog tries to recognize events by using clustering techniques. The identified events are used to structure a micro-blog about the user travels.

3 Our Approach

Taking into account the classification of context-aware groups, our proposal can be classified into groups one and three. Figure 1 presents an overview of our system, which is divided in three main parts: Data Acquisition, Data Processing and Publishing. Data Acquisition concerns the sensor application, note writing, data capturing and every other data collection process. After that, all acquired data will be processed in the Data Processing. In this part, the system uses the raw data in order to capture inferred information and to suggest a textual annotation. When the user context is properly collected and inferred, the Publishing part initiates its process. Finally, a new content is formerly produced and can be shared in the Internet, taking into account the association of each context information.

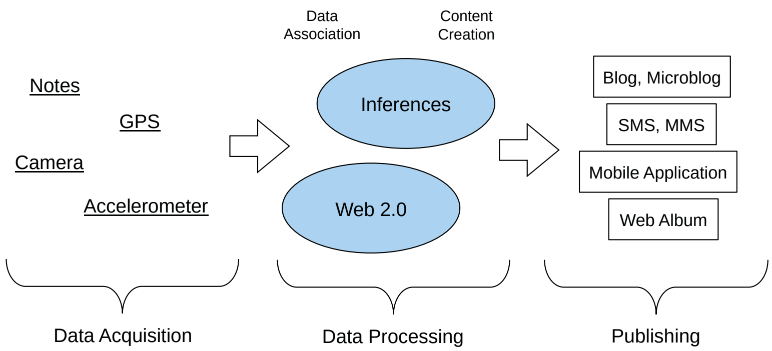

Figure 1. System Overview.

For instance, a user is registering the trajectory of his/her boat trip using our system. While he/she is arriving in the harbor, he/she decides to take a photo of another boat. At this moment, besides the photo, the sensors acquires context information, such as position, direction, speed and weather[4]. The collected data is manipulated by the second part in order to acquire inferred information and to suggest textual annotations to the user. After validating the annotations and association with the photos, the user can visualize his/her augmented trajectory and publish the content on the web.

Nowadays, one of the main features of context-aware systems is the location tracking. Our system also relies in this feature. It gets the mobile device position periodically by GPS and derives the trajectory followed by the mobile. In addition, GPS collects the geographic location of a taken picture to add this information in the metadata. This action is important to help the content generation as well as to acquire new information (e.g., weather) of a photo that was previously taken. These three parts of our system are detailed in the next sections.

3.1 Data Acquisition

One of the most important parts of our system is the data acquisition. It uses the sensors in the mobile device to get information about localization, device orientation, speed, time, etc. In addition, some initial notes made by the user are also considered as *Data Acquisition*.

During the data acquisition process, we have to do the relations between each information collected, as presented in Figure 2. According to the Figure, the user starts the data acquisition process in the mobile device. The tracking mechanism, then, begins to register the user trajectory. While the tracking mechanism is running, the user decides to take a photo, creating a new event. At the moment, the parameters of the digital camera are defined. Besides that,

[4] weather will be acquired if an Internet connection is available.

the context information is gathered using sensors. Other kind of information can be obtained if an Internet connection is available, such as the location name and weather conditions, both using the position information acquired by the GPS.

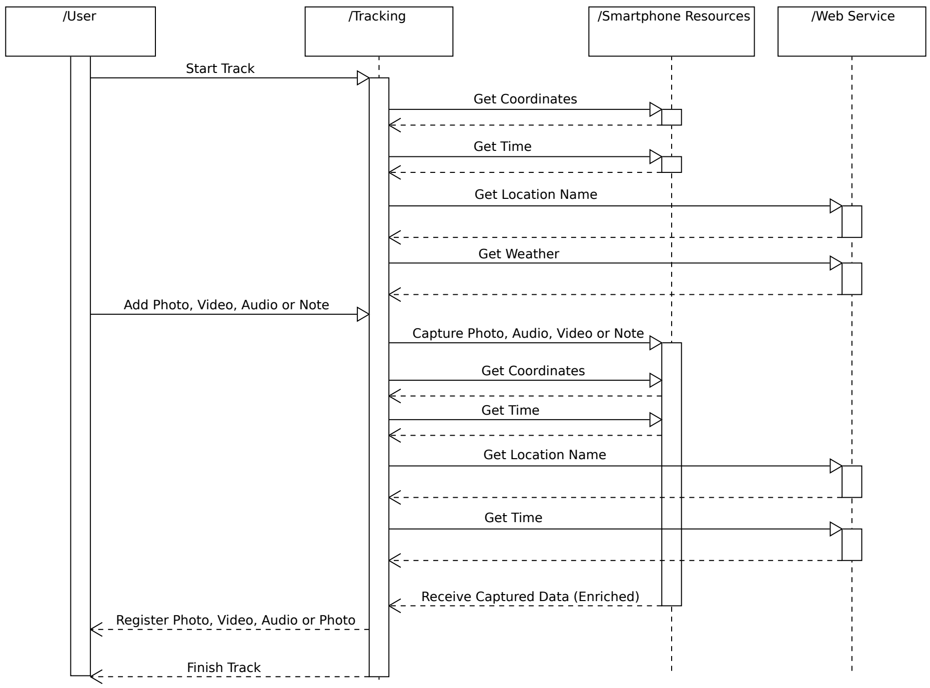

Figure 2. Sequence Diagram of Data Acquisition.

Since we are working with mobile devices, the efficiency of our system is directly related with the battery consumption. To reduce the overconsumption of battery, we propose the insertion of a distance filter in the tracking mechanism. The key idea is to avoid registering coordinates for short distances. Consequently, we have to observe what is the best distance filter value to register the coordinates. For example, we define the distance filter equal to 10 meters, the mobile device will register the current position in the metadata if it is higher than 10 meters. Otherwise, it will be dropped. The distance filter is an important feature of our system because it is responsible for the relation between battery consumption and trajectory construction.

In order to improve the data processing step, it is important to organize the acquired data into the metadata. Therefore, we used *tags* to arrange each information in the metadata.

3.2 Data Processing

The *Data Processing* is the real core of the system. It is responsible to increase the robustness of our system by offering more than a context-aware data collector, as follows. It associates, suggests and organizes the information in order to provide a comprehensive structure to be published.

Making use of the acquired data organized by tags, the data processing part is started. It has to provide an interface for users to facilitate the content generation. The key idea is to use the context information of a data to suggest the text that will be published. Our system provides an initial recommended text based on the information acquired by the mobile application. For example, if a user is registering his/her trajectory and takes a photo in a specific position, the system will generate a new photo with the name *IMG0001* and will register the coordinates *45º10'0"N, 5º43'0"E* at *15:00* on *03/02/2010*. Besides that, the user adds a note describing some characteristics of the photo. According to Figure 3, a text is suggested for each acquired data. Following the previously example, if the user selects the photo $IMG0001$ in our system interface, then a new text might be suggested: *"The photo IMG0001 was taken on the location* $< location\_name >$ *at 15:00 on 03/02/2010 and the weather was* $< weather\_status >$. $< additional\_note >$*"*.

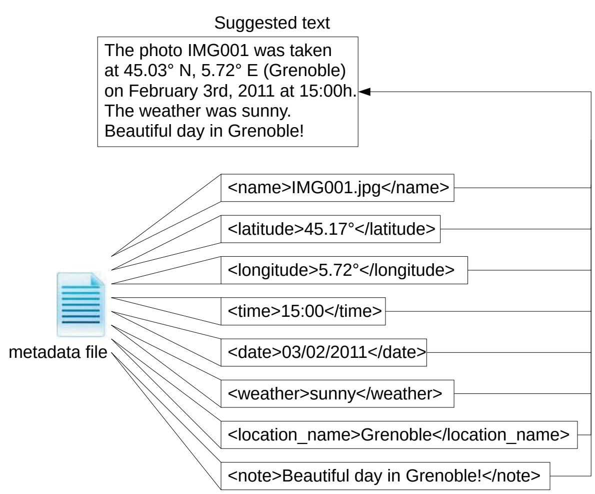

Figure 3. Data Processing.

If the mobile device due to an absence of connection does not acquire the information of location name and weather, our system interface has to be able to obtain this information based on context information. Nevertheless, the specialized web services provide the weather status for present and future times. To solve this problem, we propose a mechanism to capture this information using a HTML parser in order to get the location name and weather status for the past time. This parser reads the web page $DailyHistory$ of the $WeatherUnderground$ and obtains the weather status related to the context information provided by the acquired data. When the user generates the content to describe all events registered during his/her trajectory, the third step of our system can be started.

3.3 Publishing

The last part of the system is responsible for publishing the content produced. In Figure 1, we have proposed some applications to publish the content, such as microblog, SMS, mobile application, etc. In spite of the existence of a large number of applications to publish the content generated by our system, we choose the web content publication on blogs/microblogs because of their natural manner to publish the web content. Their structure, based on individual posts, is perfect to publish a data with context information. We can use the natural content organization to sort the posts in terms of the context information. Moreover, the user could view the content organized by day or by place, for example.

In addition, we propose a map-based interface and pop up windows in order to present the content (annotations, photos, audio, video and context information related to a position) in the trajectory. We intend to use map-based interfaces taking into account the usability studies presented in the literature [16][2]. These works show that map interfaces demonstrate more interactivity advantages than browsing information with hierarchical links. Moreover, with a map-based interface, we can easily illustrate the trajectories generated by the mobile users together with the context information.

4 Using the proposed system in a real situation

To evaluate the efficiency of our system in a real situation, we implemented our proposal for the ZeroCO2 project [17]. We designed our system to be a digital logbook during a boat expedition around the Mediterranean Sea. The logbook, which was created as a book to record readings from the ship log [18], is an essential instrument to the navigation and has to be used daily. In general, the crew uses paper-based logbooks to register all information and, frequently, the information is collected from distinct equipments. Hence, we concluded that our system was able to create a complete logbook for this boat expedition. In addition, the challenging scenario of the sea added some problems involving the recurrent absence of Internet connection and the lack of battery charging.

Our system was responsible to track the trajectory followed by the boat, adding all context information to each registered coordinates. Although our system proposes the use of audio, video and photo as data, we used only photos for this first experiment in the project ZeroCO2. Taking into account this scenario, we face new challenges that have motivated us to improve the context-aware system proposed in the previous section.

4.1 Challenges and System Improvements

When using any context-aware application in the sea, we have to handle new challenges in order to avoid problems in the application and information loss. The main difficulties that we consider in this work are detailed as follows.

- **Lack of continuous Internet connection**. In a sea expedition, frequently, there is an absence of Internet connection on mobile phones. 3G or 4G signal is perceived only when the ship is near the coast. Some high-level context information, like a location address, can be computed in a future moment (i.e., when an Internet connection is available). However, some other data cannot be easily recovered. For instance, Weather Forecast services only provide real-time information. For this reason, a special context "cache" system should be designed for providing past context information.
- **Robustness:** the absence of Internet connection and the movable nature of a ship expedition make the remote repair of the mobile application impossible or in situ. Thus, the mobile application has to be reliable. Previously, our research team has also developed context-aware multimedia systems following the architectures of PhotoMap [9] and CoMMediA (Context-Aware Mobile Multimedia Architecture) [1]. Therefore, we tested both projects that adopt Java Mobile Edition as mobile platform. In the user tests of these systems, some memory overflow incidences occurred caused by simultaneous access to the GPS sensor and the camera phone. This problem occurs even when using synchronized threads, and, sometimes, requires redeployment of the mobile application.
- **Energy limitation to recharge mobile devices**. Another critical problem found in the PhotoMap and CoMMediA projects was heavy energy consumption during the use of the mobile application. For instance, in forty minutes, the battery of a Nokia N95 was fully discharged since GPS, photo camera and Bluetooth sensors are greedy in energy consumption. In some ship expeditions, electric energy restrictions are present and the mobile application should be designed to overcome this issue.

Based on the system overview presented in Figure 1, we decided to divide the digital logbook in three parts: a mobile application to register the boat trajectory; a desktop application to receive the acquired data and generate the web content; and a blog to publish the content.

An overview of the digital logbook is presented in Figure 4. The *Data Acquisition* process was developed in the iOS platform, since the user-friendly interaction is well known in this mobile platform. The mobile application performs the boat tracking, take the photos, and carries out the relation among each data and its context information. It is important to note that some of *Data Processing* features were also implemented in the mobile phone, such as the inference mechanism to get the weather status and location name.

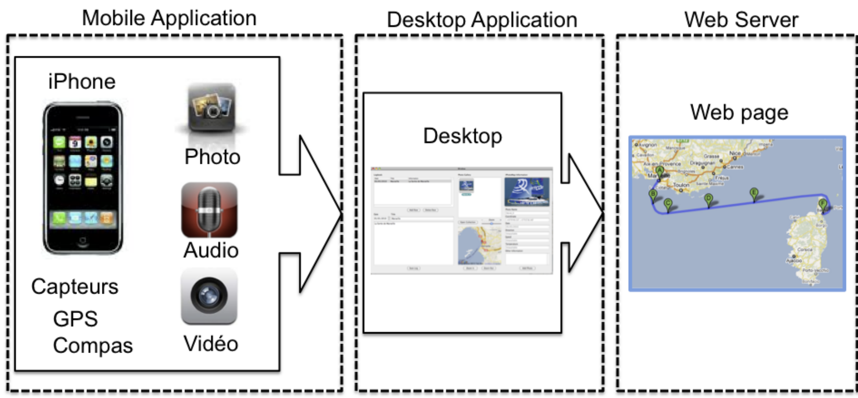

Figure 4. Digital logbook parts.

The *Data Processing* step was implemented as a desktop application to offer an interface of creation and publication of web content. It implements the module to get the context information that was not acquired by the mobile application, using the HTML parser. Another important feature in the desktop application is the function of text suggestion for each photo. We tried to develop a robustness and intuitive interface user interface to improve the usability.

The *Publishing* step was developed using an open source blog solution, which is available on the web page of the ZeroCO2 project[5]. It shows the complete digital logbook, containing the content generated by the crewmembers and the map with the boat trajectory.

4.2 Mobile Application

The mobile application interface is shown in Figure 5. As we can observe, there are two main functions: the tracking mechanism and the digital camera. The tracking mechanism is responsible for registering the geographic coordinates to construct the trajectory. The interface shows the position, speed, date and, if Internet connection is available, wind speed and humidity. The digital camera takes a picture and, automatically, adds the context information to it. There is also the option "Tag" with which you can add the information manually.

An important result discovered during our tests is related to the use of metadata following some standard, such as Web Ontology Language OWL [19]. Several solutions adopt this language to obtain inferred information about a context. However, it needs to add a large number of information in the metadata file to perform this task. Consequently, the mobile application generates several unused information into the metadata file, causing some problems of memory overflow in the mobile application. Therefore, we optimized the content of our

[5] www.zeroco2sailing.com/blog/

(a) Tracking mechanism. (b) Digital camera.

Figure 5. Tracking mechanism and digital camera.

metadata files registering only the relevant information. Besides that, we developed our own local parser to get the information of each tag and to infer about context information using the HTML parser.

4.3 Desktop Application

The desktop application interface is shown in Figure 6. As stated, the desktop application has two segments: the editing area and the visualization area. In the editing area, the user can add an annotation based on the text suggestion function of our system (Figure 3). Besides that, the user is able to edit previously annotations. In the visualization area, the application shows the photo album jointly with all context information about each selected photo. A small map shows the position where the selected photo was taken. In addition, this interface permits that the user captures weather status of a photo, in case this information was not captured at the moment the photo was taken, due to an absence of Internet connection. This is only possible due to our proposed HTML parser (Section 3.2).

4.4 Web Application

The web application is a microblog solution, in which each annotation created by the crewmember is posted. Some parts of the blog are shown in Figure 7. All content generated by the user in the desktop application is stored in a MySQL

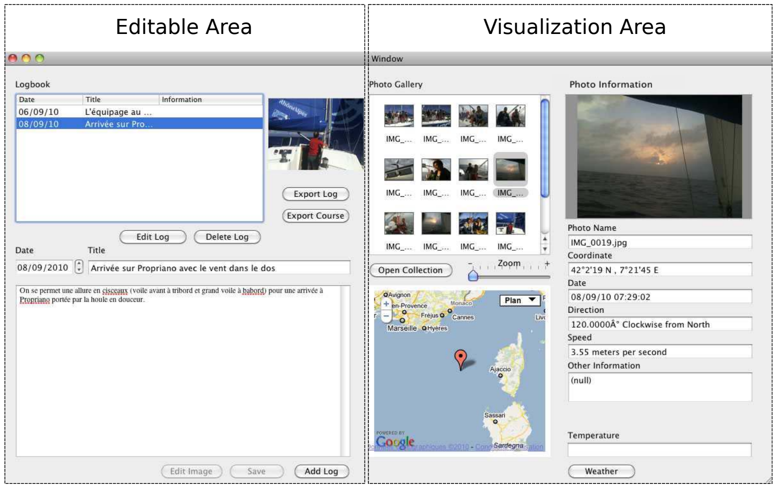

Figure 6. Desktop Application Interface.

database and consulted by Java and PHP scripts. In addition to the illustrated posts, it also presents a map showing the trajectory of the boat. This map was developed with the Google Maps API [20]. We developed our map-based interface taking into account the usability studies presented in the literature [2] [16].

The web application also performs an indexation process to improve browsing and interaction procedures. The amount of multimedia and context information increments quickly in our system. Then, to avoid future performance difficulties related to the large number of access, spatial and temporal indexes are associated with each annotation in the MySQL database.

5 Results

In this section we describe the performance and user evaluation of our system.

5.1 Performance Evaluation

The first evaluation was done during a travel around the Marseille coast. We ran this first test to calibrate the distance filter option and to execute the performance evaluation in the mobile phone. As explained before, this option is responsible to define the detail level of the trajectory. We assigned the value fifty meters to the distance filter, which means that a position will be registered if it is higher than fifty meters in comparison with the last position registered. With the first results, we refined our system to the second test: a travel from Marseille to Ajaccio (Corsica Island).

Figure 8 shows the performance evaluation of our application in the mobile phone during the interval from 26 to 29 minutes. The evaluation was conducted during the first tests, using the XCode Instruments [21] version 2.7. We observed that the *Total Load* (i.e., System and User) and the *Physical Memory Free* followed the same behavior while the mobile application functions were in operation. According to the results, the tracking mechanism requires approximately 10% of the memory and 25% of the processing to capture and register the positions. Likewise, while the iPhone digital camera is working, the memory used is approximately equal to 80% and the total load did not change. After taking the photo, the function *Save Photo* can be selected. When the *Save Photo* function is activated, the maximum load is used to associate and register all data and context information in the hard disk. Finally, the memory is cleaned when all data and information are associated and saved and the total load returns to follow the tracking mechanism. These results were important to guarantee that the user can use the application for a long time without stopping it due to memory or processing overhead problems.

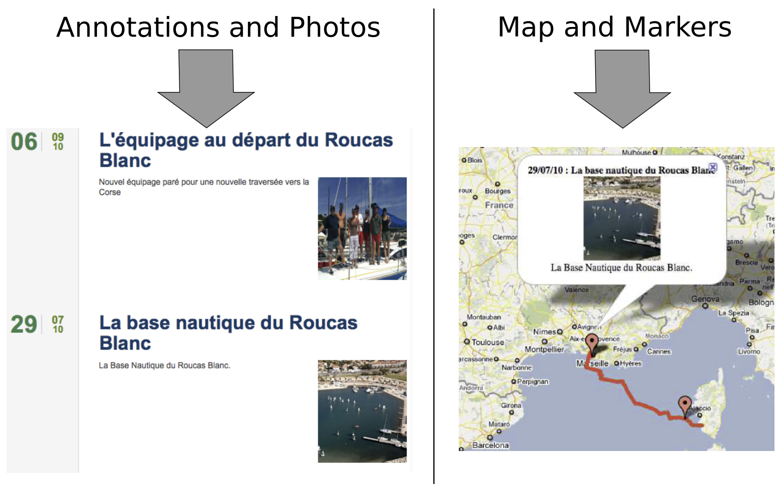

Figure 7. Web Application.

Other important results are related to the mobile phone battery consumption during the trajectory registration. In the first test, when the distance filter had been configured to register each movement of the user, the iPhone battery level was down to 10% after 2 hours. After setting the distance filter to fifty meters, the iPhone battery level was down to 10% after 3 hours. Another factor that can affect this result is the frequency that photos are captured.

5.2 User Evaluation

Once the first distance filter adjustments were performed, our system was used by three ZeroCO2 crewmembers. After a one-week expedition, the users filled in a general usability survey. Despite the small number of users, we have tried, with this questionnaire, to measure the main benefits and issues of our context-aware annotation proposal. We also wanted to know if using a mobile phone in an "adverse environment" could disturb the real ZeroCO2 missions. The following survey questions were asked:

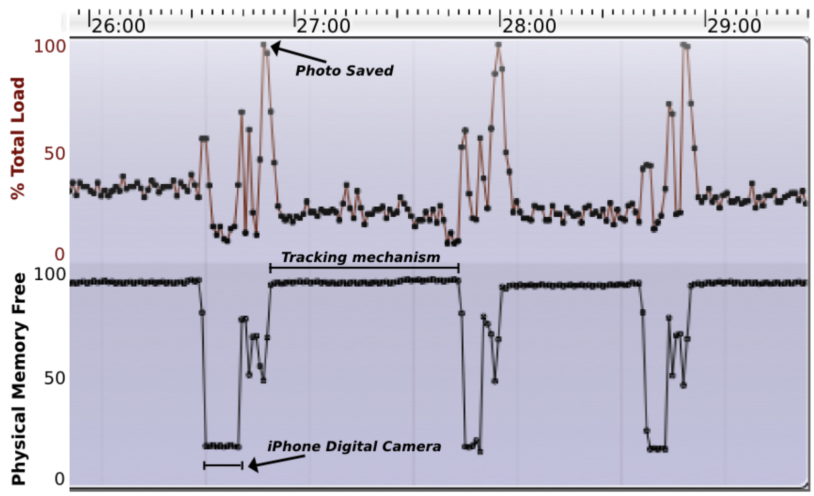

Figure 8. Physical Memory Free and Total Load in the iPhone.

- Rate how easy it was to create a digital logbook without and with our digital logbook.
- Rate how fast it was to create a digital logbook without and with our digital logbook.
- How do you qualify the accuracy of the digital logbook generated annotations?
- Could you describe the main digital logbook advantages and shortcomings?

For the first three questions, a five-scale graph was provided in which the number one corresponds to a very bad rate, and five corresponds to very a good rate. For instance, for question 1, the number one corresponds to very difficult, and five corresponds to very easy. Figures 9 and 10 show the experiments results for the first two questions.

Without our system, the crewmembers have to synchronize all information collected by a digital camera with a desktop application (e.g., a word processor) in order to create a digital logbook. Additionally, another step has to be performed for publishing the logbook information on the web (e.g., using a blog authoring tool). With a mobile device and the digital logbook, most of the processes of logbook creation, edition, and publishing are automated by our proposal. The survey results presented in Figures 9 and 10 reflect the differences between these

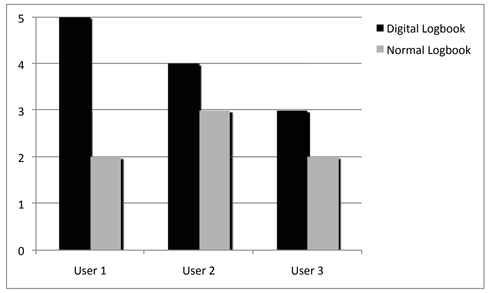

Figure 9. Easiness comparison between our digital logbook and normal logbook tools.

two approaches. Interestingly, two users have given a greater difference in scores concerning the time question (Figure 10), which shows how fast it is to publish information with our digital logbook.

Regarding the accuracy question, two users have scored "precise", and the other one has scored "very precise". Despite the use of distance filter option, one can see that the generated annotation is still very satisfactory for the users.

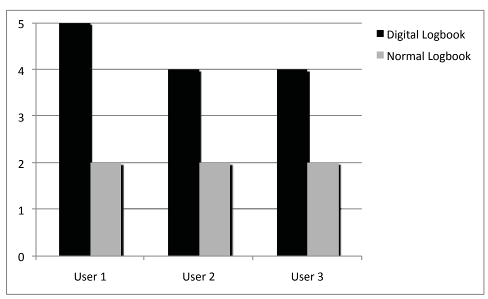

Figure 10. Annotation time comparison between our digital logbook and normal logbook tools.

For question 4, the users have highlighted the advantages of intuitive interface on the iPhone application, and the simplicity and speed for logbook creation. None of the users have mentioned disruption on their daily missions. However, the synchronization between the iPhone and the Mac book was pointed out as the main drawback. Two users have even suggested skipping this step by editing the information on the iPhone and publishing them directly on the Web.

With these results in mind, the generation of context-aware annotation is, as we expected, a useful way to automate multimedia edition and publishing even in an "adverse environment".

6 Conclusion

In this paper, we presented a new context-aware web content generator based on personal tracking. It is a context-aware system for the creation, annotation and sharing of multimedia content. We showed that our solution was used as a wizard editor for the generation of a real digital logbook. By designing a practical and efficient strategy, our system provided a user-friendly interface and offered a mechanism for context acquisition that avoids battery overconsumption and memory overflow.

Usability and performance tests were also performed in collaboration with ZeroCO2 project. The user evaluation results demonstrated that the crewmembers were comfortable using our system and found it an excellent tool to accurately publish context information according to the geographical position. Beyond our approach for context-aware systems, another important contribution is associated with the development of a context-aware photo management tool on smartphones.

As future work, we aim to offer a framework for the development of context-aware systems. This framework will provide a collection of procedures able to acquire, store, increase and infer contextual metadata related to multimedia document. The key idea is to reuse our proposal in several types of scenarios, for example: tracking an excursion in forests and mountains; studying the behavior pattern of a vehicle based on its speed, course, and position; mapping the course of runners and other athletes; and applying that for mobile learning lectures such as Geology courses that are usually taken in the field.

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