

# Application of Usability Engineering Methodology in the Analysis, Design, And Implementation of a Graphical User Interface for a Flash Flood Warning System

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## ABSTRACT

*In this paper we present a Real-Time Flood Warning System (RTFAS) which integrates information, collected and processed by the United States Geological Survey (USGS) and the Civil Defense (CD) and provides that information to local government agencies. The interface for a Flash Flood Warning System will notify the users about potentially dangerous events happening on rivers and lakes in Puerto Rico. The development of the system is based on the principles of human-computer interaction and usability engineering methodology. This methodology facilitates the preparation of a user-centered, flexible, and robust user interface.*

## 1. INTRODUCTION

Floods are the most destructive and costly of all natural disasters in the United States and Puerto Rico, in terms of loss of life and property. Just by 1983, there were almost \$5 billions in property damages [Hydro85]. The average of property loss, between 1940 and 1982, was estimated in \$1.5 billions annually. On the other hand, the loss of life due to floods varies greatly from year to year, but since 1970, the average has increased to 200. In Puerto Rico, one of the most severe floods occurred during October 1995. The result of a nearly stationary depression caused damages to 3,000 homes, 170 deaths and \$125 million in property damage [USGS89]. Most of the flood-related deaths are caused primarily by flash floods. The flash floods are considered as flood events, which occur quickly, generally in less than six hours after the causative event.

A flood-warning system can reduce losses by increasing the length of warning time in which a community can react to a potentially damaging event. Given the extra time, the response can be improved. An effective flood warning, along with an effective preparedness plan can decrease loss of life and flood damage [NWS97]. For example, the National

Weather Service has said that timely warnings and forecasts save countless lives and aid disaster preparedness, which decreases property damage by an estimated \$1 billion annually [Stallings89].

## 2. PRECIPITATION AND STREAMFLOW NETWORKS

In Puerto Rico there are two major networks of precipitation and streamflow gaging stations. One of these is a cooperative flood-warning system called Automated Local Evaluation in Real Time (ALERT). This system consists of 40 automated reporting river and rainfall gages and radio signal-receiving equipment at a base station (see figure 1). The ALERT System is operated and maintained by the Civil Defense.

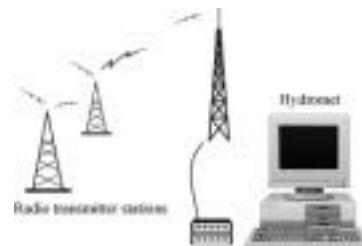
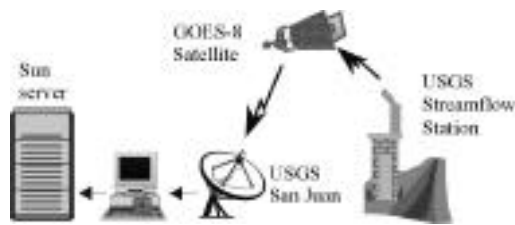


Figure 1. Civil Defense Network

The other network is operated and maintained by the U.S. Geological Survey. It consists of approximately 123 automated stations, data collection platforms, that transmit the data, either on a self timed or random reporting basis through a Geostationary Operational Environmental Satellite (GOES) to the USGS office in San Juan (see figure 2). The data collected by the USGS include measures like river stage (height), discharge (volume), lake elevation, and precipitation. During normal operation these stations transmit data every 4 hours. Under storm conditions, when a sensor detects a sudden rise in precipitation or in the river stage, the station goes into an alert mode and transmits every 5 minutes.



**Figure 2. USGS Data Collection Network**

The Doppler radar, maintained by the National Weather Service is another source of information. This radar generates color images and provides information like instantaneous and cumulative rainfall of Puerto Rico vicinity. The information provided by the agencies mentioned above is used by the Puerto Rico Aqueduct and Sewer Authority, the Electric Power Authority, the Civil Defense, and the National Weather Service, among others.

### **3. PROGRAMS USED FOR FLOOD WARNINGS**

The following is a brief description of the computer programs used for monitoring rivers and lakes including the steps a user needs to follow in order to retrieve data during a flood event.

#### **3.1 Brief Description**

The user communicates with the USGS via modem and load about three programs to get the desired data. Obviously, it depends on user needs. The most important computer program is ADAPS (Automated Data Processing System). It consists of a collection of computer programs and data files that form a system of standardized water data-processing procedures. Other programs are *rtrain* (shows total rainfall for the specified period of record (up to seven days) and *rtstage* (provides the latest update in stage of each station). All of these are character based computer programs that runs under UNIX environment.

The Civil Defense and other local agencies use a computer program developed by the National Weather Service called Hydromet. Each agency has an antenna for receiving the data sent by the Civil Defense's stations and this data can be displayed using Hydromet. Basically, the data transmitted is precipitation.

#### **3.2 Disadvantages of Current Computer programs**

There are several disadvantages and limitations in the present system and some of them will be mentioned briefly. In the USGS, most of the computer programs used for alert are character based and the user needs to go through a lot of menus in order to set the preferences prior to get the data. For example, in

ADAPS the user has to type the station number, sensor number, beginning and ending date of period of record, and other options. In this type of environment the user needs to remember the station number because a station can not be selected by its name.

For the last two programs mentioned above, the user needs to load the program again each time he/she wants to refresh the information. During emergencies it could be worst because sometimes the user needs to perform arithmetical operations since the software does not provide what he/she needs. For example, the user might need cumulative rainfall every one to three hours. The system provides cumulative rainfall for a period of 24 hours. This forces the user to retrieve unit values (15-minute values) and add them manually. This process happens one to 4 times daily during normal times. During emergencies, the retrieval of information is every 15 minutes.

An emergency situation should be notified by the alert system. At present, the computer programs lack this feature. The sound and/or display of an alarm should be based on predefined criteria. At present, this kind of evaluation is done manually. Each local agency should define what is considered as a critical value, a critical condition, and how those values will be handled.

Another disadvantage is that is very difficult to interpret the data if the user does not know the river or lake he/she is looking or if the user does not know the meaning of the values displayed in the computer.

The Hydromet program is more user-friendly than the programs used by the USGS. This program includes capabilities like visual and audible alarms, report generation, tabular and chart displays, and others. The main disadvantage is that this program can receives and decodes just radio-transmitted signals and, because of that, it can not incorporate valuable information coming from the USGS stations like streamflow, elevation, and others.

The interface of these alert systems needs to be improved, considering the user's needs and his/her computer knowledge. A new interface should be developed in order to improve the decision-making process during emergencies. Information provided by the proposed computer systems must be precise, reliable and the interface must follow the principles of Usability Engineering.

### **4. USABILITY ENGINEERING**

It was used the usability engineering methodology in the design of the RTFAS user interface. This methodology is a systematic approach to making software easier to use. Includes techniques used for

evaluating user needs and facilitates the preparation of a user-centered, flexible, and robust user interface. Usability is associated with five attributes: learnability, efficiency, memorability, errors, and satisfaction [Nielsen93].

First of all, we carry out a task analysis in agencies like the Civil Defense, the Aqueduct and Sewer Authority, the National Weather Service and the Electrical Power Authority. The task analysis is the process of learning about ordinary users by observing them in action. It is important to understand the individual characteristics of the user, the goals, the context of the work, how the user performs the tasks, and what kind of information the user needs. Based on that the interface was designed and will be explained in the following section.

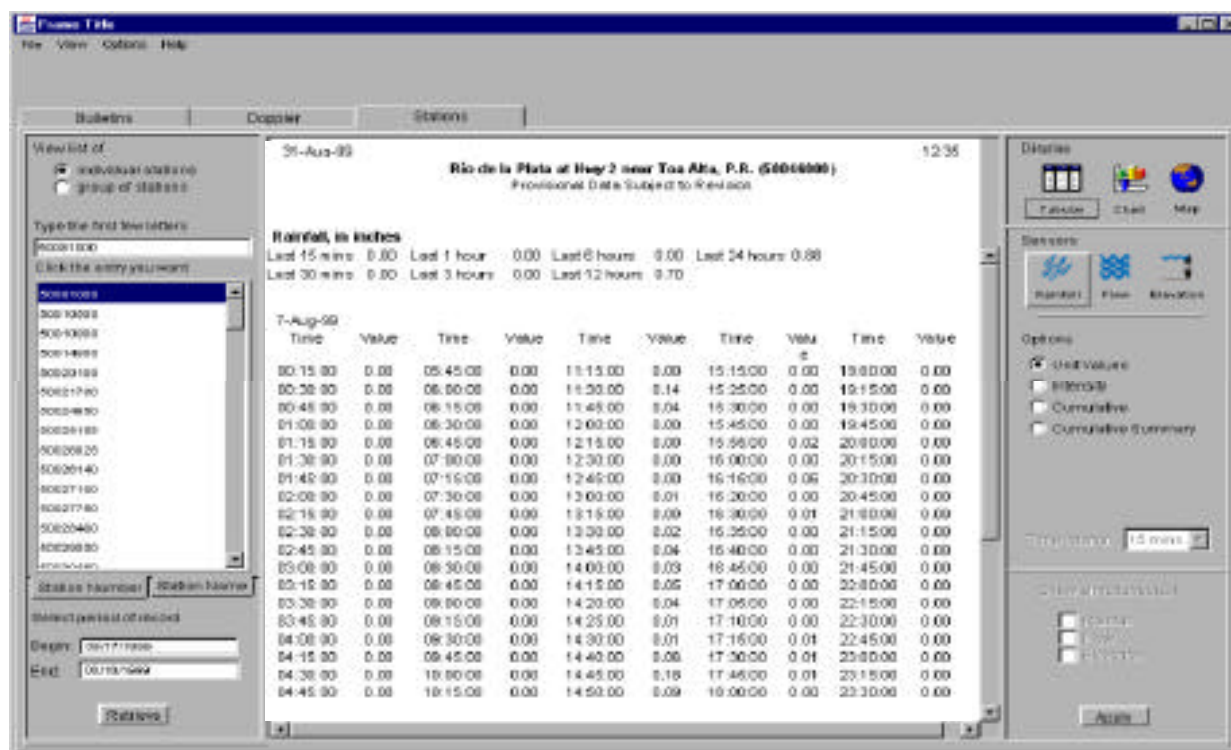
## 5. RTFAS ENVIRONMENT

The goal of the RTFAS environment is to reduce the time needed to get the status of rivers and lakes and to allow any user to interpret the information he/she receives. The graphical user interface of this system should allow the user to have an effective interaction and achieve maximum performance with the system. For example, 100% of the users should be able to find information about stations within no more than few minutes. Also, the system should provide the

user with multiple ways to exchange information. The proposed system would integrate information, collected, and processed by the USGS, Civil Defense, and National Weather Service to provide a broad range of sources of information.

The environment of the RTFAS is being developed using Java. Some advantages of Java are that it is a platform-independent language and can be used to develop applications (program that runs on user's computer) and applets (application designed to be transmitted over the Internet and executed by a Java-compatible Web browser). The local and federal agencies will have access to the information using any browser like Netscape, Microsoft Explorer, and others.

The RTFAS environment consists of a window composed of three parts. The left side of the window is the area in which the user can select the station/s and the beginning and ending date of the period of record (see figure 3). The user does not need to remember the station number because the station can be selected by name, too. The date fields have, by default, the current day because during an emergency, the data required corresponds to the current day. The right side of the window has buttons that represent the mode in which the data will be displayed (tabular, chart or map) and buttons that represent the sensors available for the selected station.



Based on the displayed mode and the selected sensor, the user can see other options. For example, if the user selects the rainfall button, the program will show some options available for rainfall. The data displayed can be cumulative rainfall, unit values or intensity. If the user wants to see streamflow or elevation, the user can see options for maximum peak flow and when it happened, full bank stage, etc.

The center of the window is the area in which the data will be displayed. At present it can be done in three modes: tabular, chart and map. Other features like automatic alarms, images of Doppler Radar and NWS bulletins need to be implemented.

### 5.1 Tabular Display

In this mode the information can be displayed in tabular form (see figure 3). Here, the user can see date, time and the values for every time the sensor collected the data.

### 5.2 Chart Display

In the chart mode the user can display a chart of each sensor/s based on the options selected (see figure 4). To facilitate the interpretation of the data the streamflow and elevation charts can plot a line with the maximum peak flow or maximum peak of elevation. Also, a line with the full bank stage can be plotted. It helps the user because he/she can compare the values with known historical values.

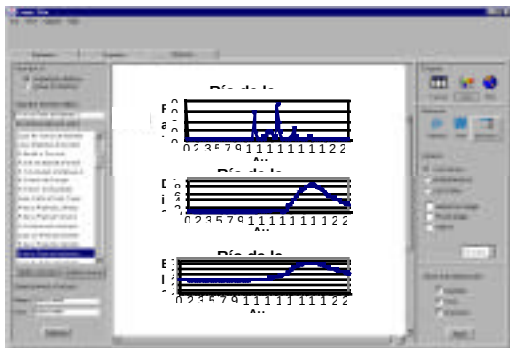


Figure 4. Chart Display

### 5.3 Map Display

In the map option the user can see a basin map with the station plotted on it (see figure 5). Each station has a colored label with a value. The color means the level of severity of that value. We use white, for normal conditions, yellow, for warning conditions, and red, for dangerous situation. Also, in the label there is an arrow which purpose is to indicate if the levels or the flow or elevations values are increasing or decreasing.

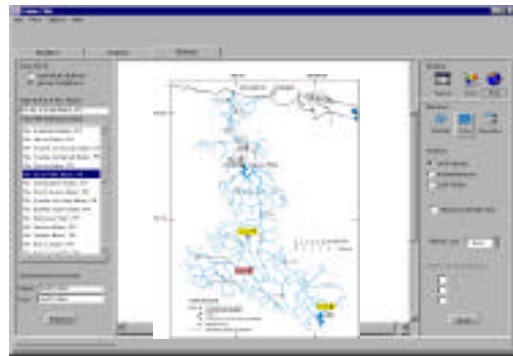


Figure 5. Map Display

## 6. FUTURE WORK

RTFAS will incorporate features like alarms to facilitate the monitoring of the stations. This is critical because in Puerto Rico, the behavior of the rivers may change abruptly. A high value in one sensor or in a group of sensors may cause an alarm. Also, the time during which the high value is maintained is critical too. The program has to evaluate present and past values because the pre-conditions can increase the risk of a flood. It is important to know the height of the flood crest, the moment when the river is expected to overflow its bank and the time when the river is expected to recede to its bank. This information will be relevant depending on the moment in which the events and the preceded conditions will take place. An alarm will notify the user of a specific situation that is pertinent to him/her. At present, this feature has not been implemented in RTFAS.

A challenge with this system is the integration of data coming from different sources. Right now, the RTFAS handles data coming from USGS stations but need to be incorporated the data coming from the Civil Defense network and the images or Doppler Radar.

## 7. REFERENCES

- [Hydro85] Hydrology Subcommittee of the Federal Interagency Advisory Committee on Water Data, Guidelines on Community Local Flood Warning and Response Systems, August 1985.
- [Nielsen93] Nielsen J., Usability Engineering, AP Professional, 1993.
- [NWS97] National Weather Service, Automated Local Flood Warning Systems Handbook, Weather Service Hydrology Handbook No. 2, 1997.
- [Stallings89] Stallings, E., National Water Summary 1988-89 - Flood Forecasting and Drought Prediction by the National Weather Service, United States Geological Survey Water Supply Paper 2375, 1989.
- [USGS89] US Geological Survey, Puerto Rico Floods and Droughts, National Water Summary 1988-89, United States Geological Survey Water Supply Paper 2375, 1989.