Regatta Management I

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Abstract— An Android smartphone application is described to be used by skippers in sailing boat regattas. It provides the information needed to cross the starting line on time and with maximum speed. The interface was specially designed to focus on the critical information, with easy reading with visual components discriminating different situations and a matching audio dimension. Moreover, the application keeps on record the whole regatta path to be viewed later. This application uses the smartphone’s GPS to receive the current position coordinates, from which boat speeds and headings are computed using a linear regression of a number of past positions. Heading angle, local speed and current position allows computing where and when the starting line will be crossed. As such, it is defined the TTL (Time To Line), which is compared on the interface with the TTS (Time To Start), the official Master Countdown to the regatta’s starting time. The system’s architecture is described followed by its detailed implementation on the Android’s OS, where some alternatives are discussed. Extensive tests were carried out concluding that the objectives were achieved with average errors of about one second and battery consumption of 75% in a three hours regatta. The application was developed for amateur and professional users with the immediate objective of being commercialized in the Android market.

Index Terms — GPS, Smartphone, Android, Regatta, Linear regression.

I. INTRODUCTION

A sail regatta is a challenging environment that can be improved if there are available technological means to help the process of decision making to obtain better results. With the current generation of smartphones equipped with a Global Positioning System (GPS) it is possible to develop an application to help the skipper in the critical phase of the competition, the start of the regatta. This was the main objective of this work, as well as the record of the whole regatta path.

A. Contextualization

To start a regatta without a penalty a boat must cross the starting line between the buoys passing with his port side on the side of the port buoy and his starboard side on the side of the starboard buoy. The jury defines the duration of the Master Countdown and signals when the countdown starts. Then, the boats maneuver to cross the starting line after the countdown ends. To make a good start the boat crosses the line a short time after the start of the regatta in full speed.

Within this context, it was considered that if a smartphones equipped with GPS was used to determine if the current course and speed is favorable or unfavorable to a good start that could improve this process. This would be possible because the GPS can read the positions and, with those coordinates, make calculations to estimate the future positions. There are other factors relevant to a good start. In this work we added the water current to compensate the deviation provoked in the course.

B. Central question

In the previous moments before the start of a regatta, how to show to the skipper an estimation of the time left in the chosen path, as to enable him to select the best combination of course and speed?

What is the key information a skipper needs in order to cross the starting line on the right moment and with the maximum speed? And how should that information be presented such the skipper receives it intuitively?

C. Objectives

To develop an application for Android smartphones with the following main functionalities:

- Estimation of the remaining time to cross the starting line;
- Interface specifically designed to be intuitively readable in a regatta environment;
- Registry of the regatta path.

The application should also:

- Have the minimum energy consumption;
- Have a low development and maintenance cost to allow a selling price below 10 Euros.
II. STATE OF THE ART

A satellite navigation system is a system that uses a constellation of artificial satellites around the Earth, allowing computing the current position (latitude, longitude and altitude).

A. GPS

The GPS: Navstar Global Positioning System is a space system of radio navigation. The system is split in three segments: space, control and user.

B. Determination of coordinates

To determine the position is used a technique called trilateration. Using the time difference between the emission of the signal and its reception, and knowing the speed in free space it’s possible to know the distance between the satellite and the receptor.

The GPS uses a tri-dimensional system of Cartesian coordinates, with the origin in the center of the Earth, the ECEF: Earth-centered Earth-fixed system. The calculations are made in this system before being converted in latitude, longitude and altitude.

C. Precision

The position precision is affected by numerous factors, corresponding to different error sources, including differences between the real orbit and the one given by the ephemeris, clock satellite errors, relativistic effects, atmospheric effects, noise in the reception, interferences and multi-path effects.

D. Local coordinates

Two simplifications can make the calculations easier and more efficient, a preoccupation of this work, because it’s designed to devices with different characteristics. In the first simplification we consider the Earth spherical, to calculate the distances and angles between two local coordinates more easily. Because the Earth ellipsoid has a 21 km in the poles and the calculations are made between two local coordinates this approximation is valid, with the exception of the regions near the poles. In the second simplification we use a bi-dimensional Cartesian system to avoid projection problems. Because this is an application for regattas the altitude is not necessary. To make this second simplification we need to use the chord between two points, instead of the perimeter of the circumference. The distance covered by the perimeter is $d_p = 2\pi r \cdot \frac{\alpha}{2\pi}$ to an angle $\alpha$ in radians and radius $r$. To the same angle, the chord distance is $d_c = 2r \sin \frac{\alpha}{2}$. For an angle of 0,001 degrees, corresponding to a perimeter distance of 1014,4928 m, the deviation between the two formulas is 1mm or 0,00000011%, so this is a valid simplification for small distances, in the regatta start process and in the regatta because the calculations are made using points very close.

E. Concurrent systems

A research was made to find out all systems available that announce some of the functionalities of this work. Table 2, at the end, compares all the devices functionalities. When referring a device this means autonomous equipment.

II.1. Prostart

It’s a device that has an integrated GPS and measures the perpendicular distance to the starting line and the remaining time of the Master Countdown. After the start of the regatta it displays and registers the direction, speed and wind changes (Velocitek).

**Sailclever**

This is an application for Windows Mobile to be used in smartphones or PDA’s. It shows the Master Countdown and estimates the remaining time to cross the line. It has six different modes to estimate the time to the line (SailClever).

**iRegatta**

This is an iPhone and iPad application for regatta tactics which can use the internal GPS or connect to external instrumentation through a NMEA connection. There is a time to line information, including the distance to the line (Let's Create).

**Sail Racing**

This iPhone application displays the distance to the starting line and estimates the time to the line (Pepette.com).

**Regatta Tactic Compass**

This is an Android application that has a starting line mode with the remaining time of the Master Countdown, time to cross the line and distance to both buoys. The buoys can be marked going near them and also over a Google Maps map. After the start it records the position, direction and speed (Embedia).

**RockBox A.M.P.D.**

The RockBox A.M.P.D. (Advance Mobile Performance Device) it’s a device with a GPS inside that, among other functionalities, has a time to line mode considered by the manufacturer in experimental mode. It has enhanced GPS precision using the Wide Area Augmentation System (available in the United States of America and Hawaii) (RockCityMarine).

**Nauteek SC200**

It’s a device with GPS with “Start Line” functionality to measure the perpendicular distance to the starting line (Nauteek).

III. SYSTEM ARCHITECTURE

A. Requisites

The objective of this work is to develop the first part of a regatta management system, with two macro functionalities: 1- Estimate the time when the boat will cross the starting line; 2- Register for latter upload the regatta path.

- Implementation for smartphones Android;
- Presentation the TTS - Time do Start with easy reading. The user can choose the total time;
- Mark the coordinates of the starting line buoys by means of: a) Press a button in the application when the user is physically near the buoy; b) Indirect position using one buoy and an estimation of the course and distance to the other buoy;
- Reading the coordinates accessing the smartphone GPS;
- Determination of the speed over ground, and the course (heading), using the current position and the recent past positions;
• Precision estimation of speed and course, so as to inform the user if values are to be trustfull;
• Display of the TTL: Time to Line, the remaining time of the boat to cross the starting line, whenever it is possible to determine its value. This value needs to be presented with an easy reading, with a sound indication plus a background color to indicate its comparison with the TTS and if the crossing of the line will be made in the correct way and between the buoys;
• Register the path of the regatta and fill in a file to be visualized later on the Google Earth.
• Use in the calculations the distance between the boat’s bow and the receptor’s position;
• Consideration of the water current effect on the TTL, if that information is inserted by the user.

B. **Global architecture**

The functional modules presented in Figure 2 correspond to a segmentation by task areas. They allow isolating the different modules for future developments without affecting the rest of the system.

![Figure 2 - Modules](image)

C. **Menu**

When the Menu is initiated it also initiates the two modules Position and Estimation. It includes several interface buttons to configure the following parameters: name of the regatta, water current (course and speed), marking of the buoys coordinates, marking one of the buoys using the other and the course and distance, and definition of the **Master Countdown**. In the end there are two buttons to initiate the modes TTL and Regatta.

D. **Position**

The position module is executed at the same time obtaining and saving the current position using the smartphone’s GPS.

E. **Estimation**

This module calculates the estimation of the position, speed and course using the recent past positions saved in the database. To smooth the values and reduce the effect of the GPS errors a linear regression algorithm is used. These calculations are activated by the position module after a new position is obtained.

After the estimation is calculated this information is made available to the TTL module, which will make the preview of the start line intersection, and to the Regatta module, who will present them in the screen and stores is in an internal file for the path upload in the end of the regatta.

The regression calculation makes available the coefficient of determination ($R^2$). A threshold value is defined, below which the calculations proceed but the user is warned about the possible information untruthfulness.

F. **Time to Line (TTL)**

This module determines the intersection point of the course with the start line and the time when it will be crossed, using the Estimation module parameters: position, course and speed. The remaining time to cross the line is called Time to Line (TTL) and is displayed on the lower half of the screen.

If the countdown clock has started, the remaining time to start the regatta, the Time to Start (TTS), is displayed on the top of the screen.

A blue background is presented when there is no intersection. If there is intersection but outside the buoys or in the wrong direction it is also shown a blue background. If it is going to be an intersection before the end of the countdown the background turns red and is accompanied by a warning acute sound with a fast pace. If the intersection is estimated to be after the end of the countdown the background turns green and the sound is bass and with a slow pace. When the TTS reaches zero, the application commutes automatically to the regatta mode.

G. **Water current corrections**

Sometimes information about the water current in the area is known. Because there is an angle between the course of the boat and its real path, by the effect of the current, it is useful to correct the TTL value to consider this fact. With a direction and speed of the water current we affect the TTL calculations to compensate the instant when the bow reaches the starting line.

H. **Time to Buoy (TTB)**

When a boat heads to the starting line in a course almost parallel to that line, the TTL value is not very useful because any course variation alters much the computed distance and correspondingly the intersection time. To this and similar situations the mode TTB was developed: **Time to Buoy**, which shows a time to both buoys ignoring the course, considering only the distance and the boat speed. It represents the remaining time assuming the boat, with the current speed, is heading directly to a buoy.

I. **Regatta**

In the regatta mode the user has the information of the course, speed and regatta time. This mode can be started directly from the main menu using a button or it can start automatically in the TTL mode when the TTS countdown
reaches zero. This mode stores the path travelled during the regatta. When the regatta finishes the user must stop the clock and can then upload the recorded path.

J. Database

A database is used to store the historic of the coordinates of the boat’s position. It is also used to optionally store the intermediate values and calculations to facilitate the analysis process during the application development progress.

IV. ANDROID IMPLEMENTATION

A. Platform architecture

The Android is an operating system for smartphones with a design based on a UNIX platform. The applications are written in Java and are executed in a protected environment in a separated process inside a virtual machine. A least privilege logic is implemented so the applications are executed with just the necessary permissions for their functionalities to create a safe environment.

The applications have four types of components (Android Developers, 2012):

- Activity (screen with user interface);
- Service (run in background for heavy operations to avoid slowing the interface response);
- Content provider (data, file system, database SQLite, etc.);
- Broadcast receiver (internal communications).

B. Implementation of the global architecture

For each module an appropriate Android resource was identified and chosen. At a macroscopic level there are three types of modules: user interface, background operations and data content. For the first situation were used activities, for the second services and for the third a database and shared variables.

In Figure 3 the bold arrows represent the data flow, the normal arrows task calling and the dashed lines a differed invocation of a service.

To protect the shared data it was necessary to use semaphores, to avoid concurrency problems.

C. Menu

The Menu is an activity that allows several configurations and launch of the TTL and Regatta modules, besides the start of the Position module.

D. Position

This module is implemented as a service, to be executed at the same time the current activity, to avoid slowing this one if it takes too long to get results. The application reads the position coordinates using the Location Manager, an Android resource. The Location Manager can use several sources to get the position: Wi-Fi, GSM network e GPS. For this application just the GPS is used because the others don’t give enough precision. When the application starts the Location Manager is initiated and its type configured (GPS), the rhythm and the conditions to update the positions, through the method Request Location Updates.

The Position Service is executed each time an update of the GPS coordinates is received. These coordinates are read and then written in the Position table of the database and in a shared variable.

E. Estimation

The Estimation reads the last entries of the Position table and makes a linear regression using the ordinary least squares method. The result is written in a shared variable, later accessed by the TTL or Regatta modules. If the values are not recent or the Coefficient of determination\(^1\) (R\(^2\)) is below the defined threshold level the estimation is considered not reliable.

F. Time to Line (TTL)

This Activity does the calculations to the start line and presents it to the user, including a countdown timer.

G. Water current correction

To improve performance this calculation is done before the TTL, by means of translating the current position appropriately. After this the TTL calculations are invoked.

H. Regatta

This module is an Activity and presents the values of course, speed and regatta time. When a regatta starts a file with the path is being constructed for later upload.

I. Path upload

While the regatta module is running a file is being written with a periodic fraction of the points of the path. In the end of the regatta the user can use the share functionalities to upload the file for later analysis in the Google Earth application.

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\(^1\) Measure of how good the model is comparing with the data. Varies between zero and one and the higher the better.
The SQLite is used because it is natively supported in Android. Because the SQLite doesn’t guarantee concurrency in multi-thread environments it’s necessary to protect the database access with semaphores in the situations where concurrency might occur.

K. Interface

The application menu has available several parameters for configuration: distance to bow, magnetic declination, course presented in magnetic or geographic degrees, name of the regatta, current course and speed and Master Countdown. In the buttons Buoy P and Buoy SB the user gives order to mark the position of the buoys of the starting line. It’s also possible to swap both buoys.

The button Dist.Buoy has an alternative option to mark a buoy using the other buoy and a direction and course.

The mode TTL is used in the last minutes before the start of the regatta when the boats maneuver in such a way as to try to get the best favorable position for the start. Because it’s a very demanding time for the skipper the interface is simplified to the most and presents just the essential information and nothing more in an easy to read form and with audio help. According with Figure 8, the background color presents the situation of the boat relatively to the line and the time when it will cross it. If the TTS has not started the color is black. The green color is used if the boat is going to cross the line in a correct manner and after the countdown reaches zero. In the same situation but if the boat crosses the line before the start of the regatta the color is red. If the boat is in another situation the color is blue. On the upper part of the screen the TTS is presented and the lower one is shown the TTL. The green situation is accompanied by a bass sound with a slow pace and the red with an acute sound with a fast pace. If the values presented aren’t considered reliable the background changes to grey to warn the user of that fact.
Inside the TTL screen it’s possible to activate the mode Time to Buoy (TTB). The information is presented on the top of the screen with the time to both buoys.

![Figure 9 – TTL with Time to Buoy activated](image)

In the regatta mode the course and speed over ground are presented, together with the regatta running time.

![Figure 10 – Regatta Mode](image)

L. **Compatibility**

The Android platform has many different devices and also many versions of the operating system. This poses compatibility problems difficult to solve and for that it would be necessary to have access to many devices and many versions and make a high number of tests.

The approach followed was to follow the development advices in what concern compatibility of the platform and test exhaustively the application in two different smartphones.

The minimum version required is the 2.2 and the versions tested were the 2.2 and the 2.3.3. The smartphones were the tnn a5 and the Samsung Galaxy SII.

M. **Performance**

The performance of the application was evaluated at two levels, execution speed and battery consumption. The information gathered in the intermediate calculations showed the process was very quick, almost always below 1 millisecond for each module. In terms of user experience the perception is also of a very quick application.

The battery consumption is in average 25% of the total charge for every 1.5 hour of use in both of the test phones. This factor is mainly attributed to the GPS but its importance is not excessive because it gives the possibility of six hour regattas or the use of an external power source.

N. **Validations**

The tests realized showed the correct working of the application functionalities and where important to detect it and improve. These tests show that the initial objectives and requirements were reached.

In Table 1 the main test list is shown. The average error of the TTL for the tests realized with the final version of the application is one second.

**Table 1 - Tests**

<table>
<thead>
<tr>
<th>Date</th>
<th>Objective</th>
<th>Work</th>
<th>Interface</th>
<th>Average TTL error</th>
</tr>
</thead>
<tbody>
<tr>
<td>17/2/2012</td>
<td>Basic functionalities</td>
<td>100%</td>
<td>Good</td>
<td></td>
</tr>
<tr>
<td>18/2/2012</td>
<td>Main functionalities</td>
<td>100%</td>
<td>Insufficient</td>
<td></td>
</tr>
<tr>
<td>15/4/2012</td>
<td>All functionalities except path upload.</td>
<td>100%</td>
<td>Good</td>
<td>0,91s</td>
</tr>
<tr>
<td>6/5/2012</td>
<td>All functionalities.</td>
<td>91%</td>
<td>Good</td>
<td>1,02s</td>
</tr>
<tr>
<td>7/6/2012</td>
<td>Study of $R^2$. Path upload.</td>
<td>100%</td>
<td>Good</td>
<td></td>
</tr>
</tbody>
</table>

$R^2$: Coefficient of determination.

V. **Conclusion**

The main component in this work was the estimation of the speed and course for the Time to Line calculation. Because using just two points didn’t allow satisfactory results, it was necessary to do a linear regression with the past positions. The linear least squares method was used because it is adequate for a situation when the speed and course is approximately constant and the error is random, like the GPS. The average error of the TTL was measured to be one second; and the battery consumption was about 25% per 1.5 h regatta time.

The initial objectives for the application were reached and this shows that with the current smartphone and GPS technology it is possible to give useful information to the skipper in a regatta specific environment.

In Table 2 is presented a comparison between the competitor systems described in I.E and this system, shown in the last row. This comparison shows that there is a market opportunity for a system with these functionalities and a low selling price.

**Table 2 - Comparative analysis**

<table>
<thead>
<tr>
<th>System</th>
<th>Type</th>
<th>TTI</th>
<th>Curr.</th>
<th>Bow</th>
<th>Visual</th>
<th>Aud.</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prostart</td>
<td>Device</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Good</td>
<td>No</td>
<td>599 US$</td>
</tr>
<tr>
<td>Sailclever</td>
<td>App. Win.</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Low</td>
<td>No</td>
<td>86 US$</td>
</tr>
<tr>
<td>iRegatta</td>
<td>App. iPhone</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Low</td>
<td>No</td>
<td>9.99 US$</td>
</tr>
<tr>
<td>Sail Racing</td>
<td>App. iPhone</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Mediu m</td>
<td>No</td>
<td>7.99 US$</td>
</tr>
<tr>
<td>Regatta Tactic</td>
<td>App. And.</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Low</td>
<td>No</td>
<td>Free</td>
</tr>
<tr>
<td>RockBox A.M.P.D.</td>
<td>Device</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Good</td>
<td>No</td>
<td>600 US$</td>
</tr>
<tr>
<td>Nauteek SC200</td>
<td>Device</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Good</td>
<td>No</td>
<td>550 €</td>
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<tr>
<td>System</td>
<td>Type</td>
<td>TTL</td>
<td>Curr.</td>
<td>Bow</td>
<td>Visual</td>
<td>Aud.</td>
<td>Price</td>
</tr>
<tr>
<td>----------------</td>
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<td>------</td>
<td>-------</td>
<td>------</td>
<td>--------</td>
<td>------</td>
<td>-------</td>
</tr>
<tr>
<td>Regatta TTL</td>
<td>App. And.</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Good</td>
<td>Yes</td>
<td>&lt;10 €</td>
</tr>
</tbody>
</table>

TTL: Time to line; Curr.: Current; Bow: Distance to bow; Visual: Classification of the visual interface; Aud.: Existence of audio information; App.: Application; Win: Windows; And: Android.

In the future it would be interesting to send the position to a server in real time and evolving to a full regatta management system.

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