ARVA II (TFG AGILE)

Joan Josep Aleixendri, Lorena Arriaga, David Duque, Daniel Gavidia, Àngel Labrador, Pere-Anton Lladós, Jared Mayordomo

Abstract

This article explains the development of the Final Grade Project ARVA II by students previously mentioned. This project has been done as a continuation of a multidisciplinary project carried out in 2015.

This Final Grade Project develops an avalanche transceiver or avalanche beacon, called ARVA or DVA. The group consists of seven members from different engineering (Mechanical, Industrial Design and Informatics). The project has been made following Agile methodologies, based on continuous iterations of the product divided into *Sprints* or increases in direct communication with the client (Eloi Martínez, head of the company Atmosferia).

This article briefly exposes a summary of the project report.

1. Introduction

The designed product is an avalanche transceiver or avalanche beacon which exists since the 70s, and it works by emission and reception of radio waves (at a frequency of 457 kHz) between two or more devices. Thought for any kind of winter mountain sport (alpine skiing, cross-country skiing, crossing snowshoeing and others), the device is attached to the user though a harness.

At power up, the device begins to emit position signal. During the activity, the device has no importance and the user do not need to interact with it. In the event of an avalanche and swept a hiker, the rest of the team puts the device into reception mode to receive the signal of the victim. At this crucial moment the speed of the team determines if the victim survives or not, because after 15 minutes the probability of finding him is reduced drastically.

2. Methodology

As mentioned in the abstract, the team follow the methodology Agile. The project is divided into *Sprints*, which will end with a *Demo* (demonstration) in front of the customer and tutors.

To apply this methodology, the team use the reference framework called *Scrum*. This framework creates (among others) two important roles for the team. One of them is the *Scrum Master* (SM) and the other is the *Product Owner* (PO). The PO is responsible of the communication with the customer to create user stories (representations of customer needs). A user story is made to develop each section of the project, written short and clear. These user stories are divided into tasks (more specific) and every member of the development team selects the tasks that he wants to develop. Each task enters the phase of the *To Do*, meaning that the task is not started. When a member of the development team selects a task and starts to develop it, it enters the phase of the *Doing*. Finally, when the task is finished, it enters the phase of the *Done*.

The SM ensures that each task is completed properly. He is also responsible of the product status and the team status. If any member of the development team has problems with his tasks, the SM has to help him and find ways to solve his problems. The progress of the team is checked in a *Daily*, a meeting of 15 minutes of duration that takes place daily. It is a hangout where each member of the development team explains the progress of his tasks and the problems that he has had developing them.

At the end of a *Sprint*, the team can perform a *Demo* with the customer and tutors explaining the increase made in the product. After the *Demo*, the team evaluates the work done during the *Sprint* (*Sprint Review*). The next step is the *Sprint Planning*, a meeting where the team can organize the next *Sprint*.

3. Objectives

These are the objectives that the team had at the beginning of the project.

- Design an avalanche transceiver that complies the existing regulations. A comfortable, easy to use and innovative device.
- Make a functional prototype using open source to emit and receive radio signals.
- Apply Agile methodology to coordinate the seven members of the team.
- Provide some kind of innovation in device functionality.
- Apply, as far as possible, guidelines and customer requirements.

Thus, once some initials goals have been created, the team met the customer and searched with him how to approach this project to have a successful outcome.

4. Previous Studies

With the purpose of having a good start, it was decided to get information about the current uses of an ARVA, as well as knowing its best and worst specifications. To do that, a market research was done while beginning a technology investigation.

There were 5 devices, currently in the market compared, and studied its features. As an added value, some professional opinions were retrieved from ARVA vendors to help determine the importance every feature has, to establish priorities.

Before creating a design there must be some basic aspects to have in mind. For example, the measures the product must have. For that, is mandatory to see anthropometric tables and decide the optimal measures to adapt correctly to people's hands. So, various anthropometric studies were put to analysis and decided a conclusion about them: the best way to advance was to focus on percentiles (groups) 25-75 (see Fig.1).

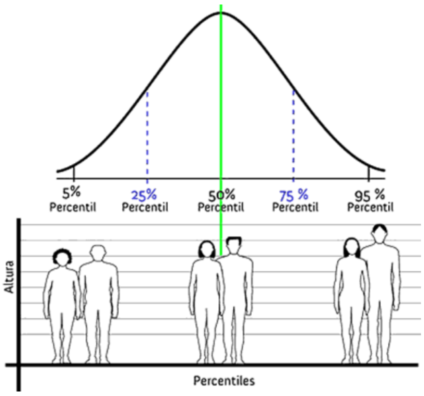

Fig. 1. *Percentile illustration (from small to large)*

As the Figure 1 shows, a P25/75 gathers a wide range of users, avoiding the outliers, warranting the creation of a balanced product speaking about its size.

Furthermore, using different volumetric models, an ergonomic study was made, showing which basic shapes would be the most comfortable and easy to handle, as is seen on Figure 2.

Fig. 2. *Different volumetric shapes*

Leaving aside design, one of the aspects of the ARVA II project I adding valuable and useful features to its final users. Having in mind that the success of them depends on how the users react to them, a poll was prepared asking about their opinion about new ideas and possible improvements on the device's usability and its features. Once arrived at the poll deadline, the first specifications were decided, thanks to the good response received, as well as necessities proposed by the client, Eloi.

- Usable for a very long time
- Better data visualization than current devices.
- Addition of a tracking system, (GPS).
- Crossed harness.
- Communication with smartphones.
- Reduced dimensions.

5. Product Approach

After interpreting the information provided by the market and the users, the developer team and the client decided to develop three product levels, addressed to different user levels, balancing features and ease of use:

- ARVA EASY: This range's objective is to satisfy beginner users, who get an ARVA to occasionally practice snow related sports. This model will be equipped with the basic RF emission and reception features between devices, and its best traits will be a reduced size and an affordable price.
- ARVA TECH: This range has as an objective to satisfy regular users who are used to practice snow related sports frequently and want to have extra features in their device. Compared to EASY series, this device will add GPS system, Bluetooth (BLE), 3G communication, and an *Android* (Google mobile operative system) app, and will be power supplied by a combination of alkaline and Lithium-ion batteries.
- ARVA PRO: This range's objective is to satisfy the most demanding users, who get the better ARVA in the market. Because of that, PRO model will have advanced features just as humidity and temperature sensors, gyroscope, accelerometer, and a vital sign tracking bracelet.

6. Product Design

Developing 3 different equipped ARVA devices it was decided to develop different device designs for every device range, or at least two of them. Almost all the features in the PRO and TECH series are present in both of them, so the difference in features is not enough to justify individual designs for each (except sensors and some modules), but there is a clear difference in features between the EASY series and the other two.

Thus, it was decided to develop two design solutions: one for the EASY series, and other for the TECH and PRO series. After analyzing the market and taking advice from the client about the team's decisions about the device's basic shapes and designs, and before starting 3D modelling, different tools were searched to use during design phase. These tools help detect possible approach errors, to correct them in an easier way:

- AMFE: Tool used in the industrial design field with the purpose of analyzing and give priority to the errors or weaknesses before they produce a potential usability problem.
- Poka-Yoke: This tool is used to avoid potential assembly and use errors (human or not) using a system only usable in one way. Is an example a USB connector, only lets users connect the device in one way.
- Models and prototypes: Building a preliminary figure of the device it's possible to study from the device's ergonomics to its ease of use. Eventually it is possible to create a testing device which can help develop the ARVA's functions.

- Force simulation: Tool that helps determine the capacity of a design to resist hits or different forces on it, using a CAD program.

Given the limited length of the article, only will be displayed the final designs of the devices. These have a similar structure, composed of two case parts joined by screws (6 M3 screws used for the EASY and 4 M4 screws for TECH and PRO). It is worth to say that during all designs, the design and material normative have been followed ([1] is the most important).

Some of the components in the devices are:

1. Motherboard and modules: ARVA EASY will have a simpler motherboard, and TECH/PRO will add modules to their more complex motherboard (3G, Bluetooth, GPS, etc.)
2. Antennas: There will be placed 3 antennas (one for every axis X, Y and Z).
3. Alkaline Batteries: 4 AAA will supply the easy series, and 2 AA inside the TECH/PRO series, that will be supported by a Lithium-ion battery.
4. 3,5mm Audio Jack: Standard in case it is not possible to see information on the screen.
5. Speaker, to get sound feedback of the screen information, and as an another solution when information can't be seen on the screen.
6. Screws and O-rings, which will keep ARVA devices hermetically closed and safe from water.
7. Different sizes OLED screen for EASY (2 inches approximately) and TECH/PRO series (3 inches approximately).
8. ON/OFF Switch and RF Emission/Reception switch: The two switches are placed on de upper part of the device, un in a double L shape and the other in a wand shape. Switches on and off the devices and tis mode (search or emitting).
9. Joystick (TECH/PRO): Used to move between menus and options in the device.
10. Protective Cases, 2 for every device.

Figure 3 shows ARVA EASY and its internal component, and Figure 4 shows the same on ARVA TECH/PRO. As it can be seen, they are similar but apply different solutions and details.

Fig. 3. *Quartering of an ARVA Easy*

Fig. 4. *Quartering of an ARVA TECH/PRO*

Besides designing the ARVA device, a concept of a harness where it would be attached to, has been created. The devices would be placed on the front part and, like Figure 5 shows, it would be placed upside down to make easier for the user to catch correctly the ARVA from the harness in case of need. The harness would be adjustable, supported on the collarbone and hooked on the back part of the harness, with another hook on the waist. That way, it would have one contact point less than the current ones, and would simplify putting it on.

Fig. 5. *Harness design*

7. Materials and Forces

Together with developing the designs, materials were searched to withstand the needs (normative and design-wise) for the devices and the harness. These materials would be tested in CAD simulations to see how they could hold endure in the conditions required by the normative [1].

So, the chosen materials for the different parts of the ARVA will be:

- Harness: Coolmax to absorb sweat, with added seams to give it the desired shape. Ripstop and Nylon strips to comply with the resistance to forces required on the normative. It will also add some polioximethylene (POM) pieces to join Ripstop and the Nylon strips together.
- Case: A combination of Polycarbonate and ABS for the basic body and anti-sliding silicon for the zones where the user will hold the devices. The permeability and air tightness will be guaranteed using O-rings on the contact zones (cases, batteries cover, etc.).

To follow the normative rules about enduring bumps and burials in snow, (see [1]) multiple simulations have been performed (using case materials) to see deformations and potential structural failures that may be.

After that there have been extracted some hypothesis: (1) burial under 4 meters of snow, (2) 1-meter device drop height, and (3) 80kg person drop on top of the device. As an example, there is Figure 6, where the first hypothesis is applied to both ARVA models. The results are better than required in all hypothesis, talking about Figure 6 the maximum deformation is 0.3mm, 3 times under what's established by normative.

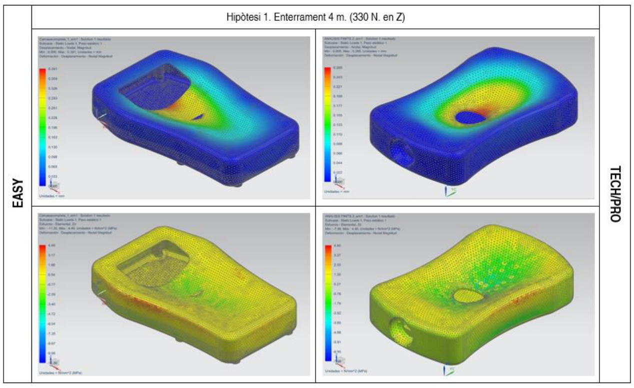

Fig. 6. *Application of hypothesis 1 (burial under 4m of snow)*

8. ARVA Technologies

Getting to a technologic approach, here are displayed some of the technologies thought to be used on ARVAs, and its implementation.

- **3G**: 3G is a communication technology that can send voice and data using a SIM card. Its possible use would be sending an emergency signal or message to 112 (or other emergency services). That should be implemented in a future, as the emergency services currently do not handle automatic signals. On 2017-2018, is expected to offer a channel for enabling that.
- **Lithium-ion Batteries**: They improve considerably usage time, comparing with standard alkaline batteries, even though there may be sudden discharges due to low temperatures. For that it is decided that ARVA EASY will only use alkaline batteries, and the other models will use fewer alkaline batteries, and a lithium-ion battery. In case the power on lithium-ion battery runs out, ARVA will guarantee its basic features using the remaining alkaline batteries.
- **BLE and GPS**: The mid-range and high-end devices will be provided with BLE (Bluetooth Low Energy) and GPS. The first one will be able to interact with smartphones and the second one will help RF system to locate the users.
- **LoRa:** LoRa (**Lo**ng **Ra**nge) is a wireless RF technology based on point-to-point communication. It lets the user send messages to long distances (thanks to its frequency range). Though it has an inconveniences: the size of the messages is extremely low, and to reach maximum distance is required a more powerful receptor too large for being added to ARVAs. Because of that it is only being theoretically studied.

From the first presented technologies, there have been implemented on the prototype Bluetooth, GPS and portable autonomy (although it is only using alkaline batteries). This has a possibility to add extra features and design improvements in a future.

9. ArvApp Android Application

As a complement to adding new technologies to the ARVA device, an Android app has been created, due to people having smartphones everywhere, and Android being an open code operating system, so it allows creating applications without cost.

This app will connect to the ARVA device using Bluetooth and will allow displaying different information and calling the emergency services without having to handle the device.

In a next iteration, the app would make use of the smartphone sensors –accelerometer, temperature and humidity sensors, etc.- to establish patterns and detect dangers; for example, when an avalanche takes place and members of the group have changed to search mode, if the accelerometer reads a sudden acceleration

This application will have another feature with an implementation of the LoRa system, allowing to see in the smartphone screen a group tracking system, to monitor all member's devices in real time. If a group member gets lost or has a problem, the group monitor would have the last received location to rescue him.

10. Prototype Development

When creating the physical prototype, it was decided to use different components to use the technologies presented earlier. So, this prototype is formed by a motherboard and microprocessor in an Arduino MEGA which contains all the code implementation, a Bluetooth module to communicate with the mobile app and send GPS data to it (GPS also included), RF emitter and receiver to communicate between ARVA devices, and finally a speaker to give sound feedback of the victim distance and a screen to display directions and distance.

It must be said that, a pair of buttons have been added to the prototype, to switch between emission and reception mode, and switch between different possible victims emitting, and each one of them individually. Each of the mode uses a different selection of components for its features.

All the prototype behavior has been implemented in C, establishing communication protocols -between different ARVA devices, and between ARVA and its Android app- and designing new data packets containing from a device identifying code (MAC Address), latitude and longitude read by GPS and a value to verify data corruption. In reception mode, the device gets data packets and decrypts them to get all the intended data and sending it to the application.

This prototype is enclosed in 3D printed cases, designed having in mind the ARVA ranges decided at the project start.

As a future commercial possibility, the modules used in the prototype and the code implementation should be embedded in a custom motherboard to reduce size and cost. This would increase the initial cost of the device (due to designing and implementing the custom motherboard), but from there, the individual cost of a mass produced device would be reduced, resulting in a lower long term inversion.

11. Conclusions

To begin with the team realized that working with agile methodologies (SCRUM) makes the project's objectives achievable faster than the standard methodologies. For an instance, the team was able to show a first version of the prototype in a few weeks after starting the project and it (the team) was able to mold and update the prototype until it reached a final stage of a working ARVA; this fact is unthinkable using standard methodologies.

Furthermore, the team is satisfied with the project because it developed a fully functional prototype and three different products (with different capabilities) for every potential customer. Also, the team improved the state of the art by implementing never seen updates in the ARVA industry which will help the users of these devices to improve their rescuing experience.

To sum up, this article describes the internals of the project's development that lead to a fully functional prototype developed by students of the EPSEVG and, although it had its problems and difficulties, the team can now show this improved device to the world.

12. Future Lines

The future lines section covers the implementations or upgrades that can be done to the finished project. The team has detected the following lines:

- Develop the correct antenna modules to communicate on the emergency frequencies.

In the final state of the project the team had to use standard radio antennas to send the information to other devices instead of the special hand-crafted antennas that are used on the ARVA because these special antennas and its modules can't be bought and creating them is a project itself

- Establish a connection between a standard ARVA and this project's ARVA.

As said in the text above, the team could not land his hands on real emergency frequency antennas and this makes impossible the communication between a standard emergency frequency ARVA and this project's.

- Implementation of the Shepherd system.

The team defined a system to create expeditions and send automated notifications to the emergency services (such as 112) but it was unable to establish the communication between two prototypes because of the lack of proper antennas. LoRa was the first answer to the antenna problem but after a deeper research LoRa proved useless to the requirements of this system.

- Develop an integrated circuit design for the prototype.

At the very end of the project the team developed the prototype on Arduino Mega knowing that, for commercial exploitation of this device, it could be all reduced to an integrated circuit which would reduce the size of the prototype and make the device more comfortable.

- Optimize the structure of the device.

Although the design of the prototype is quite robust, thee team could not test it on the real scenario. The team developed a device that's able to life through the rash conditions of an avalanche but an improvement could come in handy after the real tests.

References

[1] ETSI EN 300 718-1 *Electromagnetic Compatibility and ERM Part 1*. European Standards, 2001 Ref: REN/ERM-RP08-0409-