INNOVATIVE SMART SYSTEMS

INSA INSTITUT NATIONAL DES SCIENCES APPLIQUÉES TOULOUSE

ULTRA ORDINAIRE

PROJECT REPORT

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Abstract

UltraOrdinaire has the deep conviction to allow people developing their own creativity, inherently linked to materials and volumes. The objective: create a cross-platform application to build custom furniture models, with decoration engraving or imprinting after performing filter functions on personal pictures, and thus create a unique piece of work. Similarly, the autonomous lamp project wants to mix energy solving questions and architecture, with a design based on the technology. For main app project, we used powerful tools such as Ionic (based on Angular) and Firebase database to build a perfectly reliable app, with reusable pieces of code. Several filters have been coded based on image processing in JavaScript to truly customize user photos, and the API ShapeDiver was used to implement furniture 3D models with unique parameters. To build the lamp prototype, a pertinent state-of-the-art has been established, and finally Peltier modules have been used to generate electricity from heat loss sources and temperature gradients. The app allows user data management (sign-up/sign-in, settings, information, wish list, deliveries, historic of creation…), and the setup of 3D models and filter processes with various options. The prototype of the creative lamp is able to power a LED with four modules wired in series, and pertinent locations in the house to use this solution are reviewed (windows, parts of the floor…). Small improvements are needed within the application, but the simple process is doable by any user. The lamp utilization demands further research, but a complete report has been made with results and avenues.

Keywords: *Ionic, Angular, cross-platform app, Android, iOS, Firebase, ShapeDiver, filters, image/photo processing, JavaScript, Agile, state-of-the-art, Peltier module, energy savings, creativity, customization*

Introduction

During the 5th year and our last semester of study at INSA Toulouse, we have to realize an important project. We chose our project regarding our preferred skills and the project objective.

Ultra Ordinaire is the company we chose to work with. The projects provided by the company is mixing application programming, electronics, energy sources, IoT and image processing.

Nowadays, architecture works this way: architects design the structure, the container, without thinking about the content: the people inside. We need to have a human approach, with a more modular life space, with more freedom, a space where humans feel integrated and free.

Our project can be divided into two parts: to create an application for furniture design & to create an autonomous lamp. The application would allow a customer to customize its own furniture by changing the size and engraving pictures on it, and to ask for a quote to the company. The lamp would use an autonomous source of energy and its light level would adapt to the light level of the room.

We are a team of five members from different school education programs (electronics, automatics, computer science, networks and physics) that allows a mix of different skills to create a great final project. This report will present this team and our client, the Ultra Ordinaire company, and the two projects with their problematics, methods used and the achieved deliverables.

1. Project overview

1.1. Actors and projects

1.1.1. Client and team

Ultra Ordinaire is an association and group of research created by ***Duffau & Associés*** [1]. This company has been created by Pierre Duffau and Nathalie Bruyère in 2010 and is about practices in building architecture and design. The goal is to have a new approach of the architecture with living spaces based on the individual's place.

Figure 1: Duffau & Associés logo (left) and Ultra Ordinaire logo (right)

Ultra Ordinaire wants to contribute to a society of knowledge sharing with spaces where humans feel integrated and free [2].

Our team was composed of five students:

- **Agathe**, from physics engineering: she is creative, practices dance since she is three years old, creates video games, she likes sharing ideas to build crazy things.
- **Guangjie**, from computer science: she is from China, she started learning French two years ago and she is already bilingual. She is a boss in coding Android application, web development and data bases.
- **Jonathan**, from electronics and automatics: he likes travelling the world, thinks about going the commercial engineering field, he likes programming and software engineering.
- **Elie**, from electronics and automatics: a boss in coding, he has the sense of details and pretty things well done. He has once played nearly professional football.
- **Sophie**, from electronics and automatics: passionate about IoT and always willing to learn new things, she is very enthusiastic about using her skills to work with a designer.

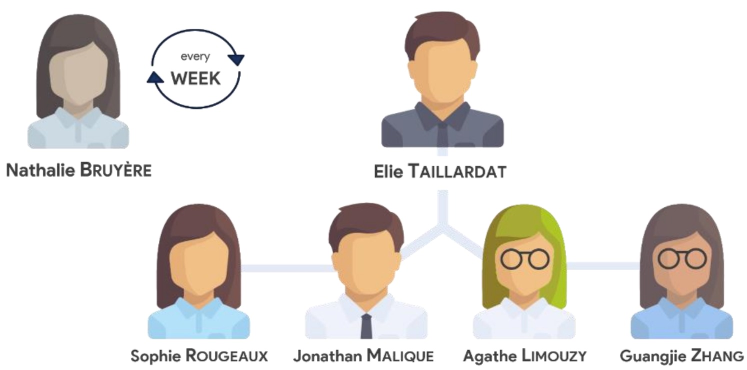


Figure 2: The project team

Together, and with our tutor Jérémie Grisolia, we were an over-motivated team, and we gathered all the skills to make this project a great achievement.

1.1.2. Two projects, one team

Nathalie Bruyère, from Ultra Ordinaire, came to us with two projects: an application development project and an autonomous and connected lamp project.

The app project had the most important place: to create a cross-platform application (available for Android, iOS, Windows, Web etc.) to build custom furniture models, with engraved or imprinted decoration after performing filter functions on personal photos or pictures, and thus create a unique piece of work, designed especially for the user.

On the other side, the autonomous lamp project aimed at solving energy and architecture questions, with a design based on technology. It has been quite challenging to solve the autonomous energy source problem because of the technology available.

We will deal in more details with these two interesting projects in the next chapters and see how we managed them. Indeed, the particularity of our team was to study not only one project, but two at the same time.

1.2. Tools and methods

To manage the timeline in a coherent and reliable way, regular meetings were held throughout the process of development. Nathalie came to INSA and had meetings with our team **every week,** with a duration of usually **one hour**.

During the meetings, we validated the design models and discussed the problems to be solved. Before Christmas vacations, we held seven meetings to monitor our progress each week. After that, we held two meetings in January to validate the app and add final modifications according to our client's point of view and requirements. This way of working allowed us to always be aware of the client's point of view and needs and forced us to have something new and with the wanted adjustment every week, which has been truly positive for us to progress in our project. We can compare this way of working with the Agile method, based on sprints that needs to be completed. As we will later, especially for the app project, this method was very useful, paired with the Waterfall typical system for each requirement and function added.

In addition, some software was used to help us to manage the project, shown on Figure 3.

Figure 3: Different tools we use for our project management

- **Trello** is a powerful tool to manage the entire timeline. With it, we planned our nine meetings and tasks to do with a deadline.
- With **Slack,** we discussed about our tasks and shared documents between the team and our client. If we wanted to contact Ms. Bruyère, we could send messages in the Slack group and

she answered our questions. It also helped to reschedule some meetings. Almost all the official communication was done with the help of Slack.

- **GitHub** is an efficient tool who is developer friendly. In this project, in order to share codes and documents, control code versions in our group and keep the resources private, we bought a professional account which cost $25 per month. In this account, we added four developers' accounts and an account for Ultra Ordinaire.
- We used **Google Drive** and **One Drive** in addition to Slack to share large documents. For example, the material (pictures, pdf…) for the application was so large that we couldn't transfer it with Slack. In this case we used Google Drive to store it.

1.3. Timeline

To have a better perception of our time division and planning, we used two models.

The first one was based on the Gantt tool, to define the different periods for our project steps, especially for the app part, with tutorial and learning periods, the front-end/back-end coding, the database… The overview of the Gant is shown in Figure 4.

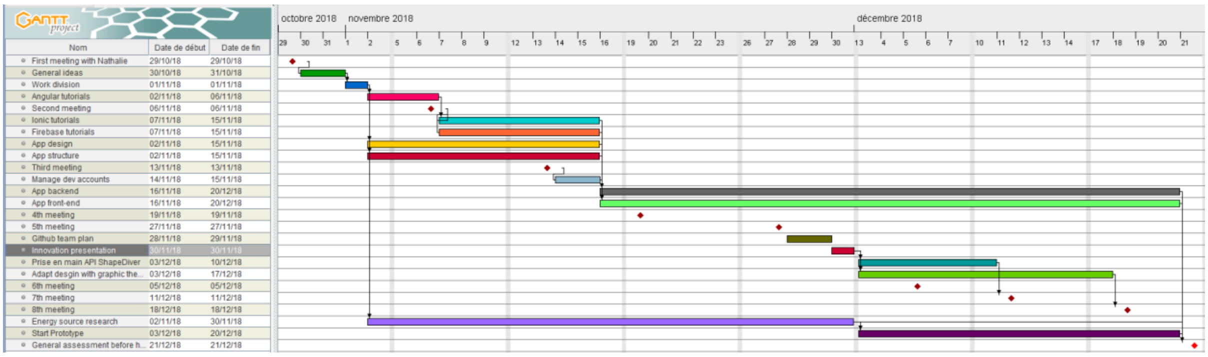


Figure 4: Gantt project diagram

The other tool, Trello, was more used as a reminder tool, with more precise deadlines according to our meetings, and what needed to be done quickly for next the sessions.

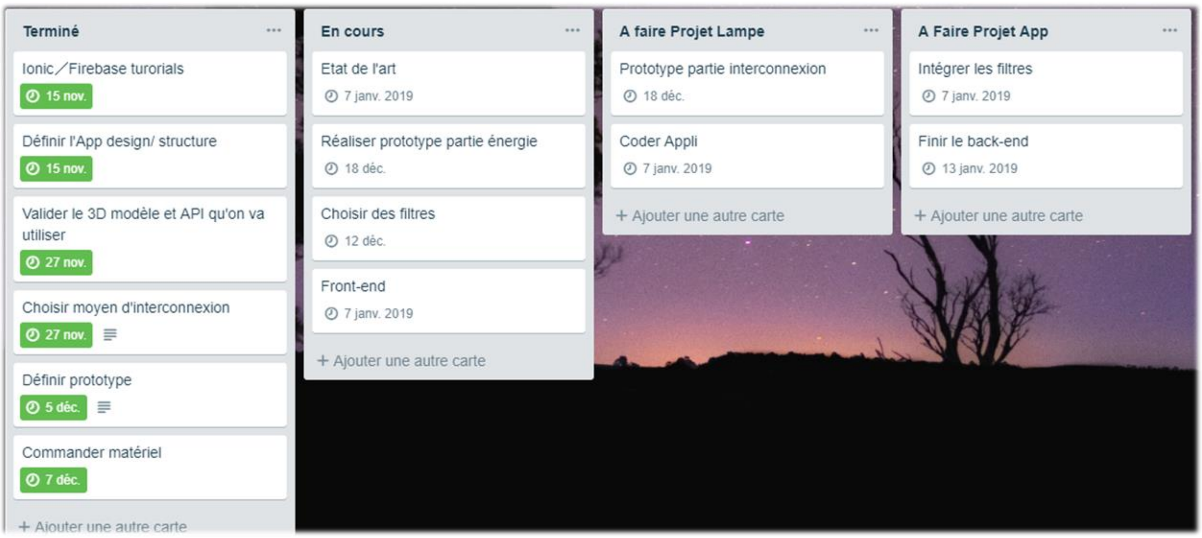


Figure 5: Trello planning view

2. Cross-platform application

2.1. Specifications

The Ultra Ordinaire app is an e-commerce application which allows any users to order their own customized furniture. This application has the same name as our client company. To be more specific, here are all the functions of this application:

- Ultra Ordinaire manages all user accounts with the help of Firebase.
- Ultra Ordinaire allows users to choose all parameters they want for the furniture, like the dimensions, material…
- Users can also filter images or personal photos by using filters and then engrave/imprint… them on the surface of the modelized furniture.
- The user interface of this application would provide four languages: English, French, Spanish and Italian.
- After having chosen the style, an order will be created, and all information will be send to the Ultra Ordinaire company.
- Users have the possibility to save their preferences, follow their orders…
- If users want to contact Ultra Ordinaire, they can send emails directly from this application.

2.2. Development timeline

Waterfall model fits into simple scenario which means we have a perfect understanding of customer's requirement and the technologies we need to use. As the requirements were quite clear at the beginning of the project (according to the last three months of the semester), we choose the waterfall model for the development, integrated in small Scrum sprints at each team/client meetings as we have seen earlier in this report.

The waterfall model [3] is a relatively linear sequential design approach which usually has five steps, as shown in Figure 6.

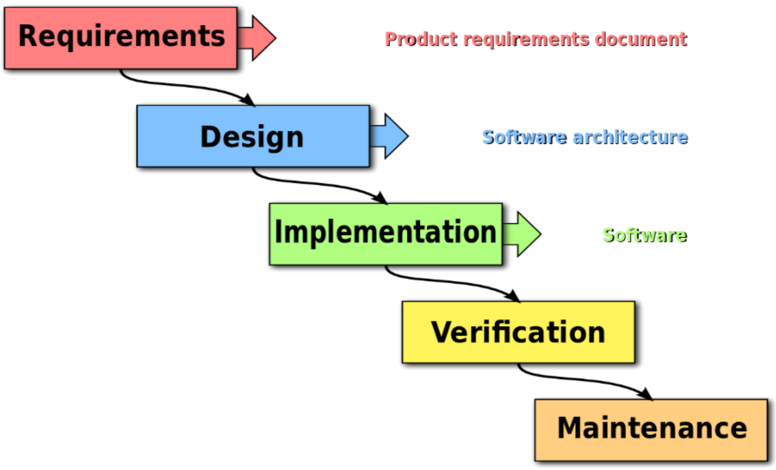


Figure 6: Waterfall model

- **Requirements:** Our client company and its representative, Ms. Natalie Bruyère, had a clear requirement at the beginning of this project, they had a list of functions expected. During the first meeting we discussed all the details and finally made decisions for future steps. That is one of the reasons why we chose this development model.
- **Design:** After analyzing the expectations of this project, we designed the first version of user interface. Then we discussed this design with our client and based on our plan, our client produced the final and second version (see A2. App specification front-end (ideas & client)). The second version was approved to guide the development afterwards.
- **Implementation**: This part is the most important part, so we started to study Ionic, the technique we used for developing, when we analyzed requirements and designed user interface. Learning how to use the Ionic/Angular tool and designing in parallel improved the efficiency and made sure that we could start coding as soon as we finished the user interface design.
- **Verification**: Tests were run both during the development and after that. During the development, each time we finished one part, we did a unit test to make sure the coded module behaved normally, and we planned a beta test at the end of the project.
- **Maintenance**: Maintenance does not only mean making the application work at all time, but also includes adding new functions. Until now, we almost finished all the specified functions. For further development, comments are provided.

2.3. Development environment

2.3.1. Ionic

Ionic is a complete open-source SDK for hybrid mobile app development using web technologies like CSS, HTML and TypeScript [4]. The more recent release, known as Ionic 4, is based on Angular, which is also a framework for websites. Apps can be built and then distributed through native app stores to be installed on devices by leveraging Cordova.

Figure 7: Ionic & Angular powerful development tools

Ionic has many advantages, it is easy to learn and quick to develop. It runs on different platforms: Android, iOS, Windows phones and in browsers with the same code. Furthermore, the Ionic framework shares compatibility with Angular, thus, the benefits of Angular development can be used too. It was so helpful that Elie chose to realize his Portfolio with Angular during the semester, which allowed a quicker app development.

However, Ionic also has some disadvantages. Compared to the performance of native mobile applications, Ionic is less efficient but in most cases, the performance gap is not noticeable. Ionic is not suited for high-end graphics dependent applications or games, but our application is just used for commerce and service use, so we could ignore this disadvantage.

After analyzing almost all the advantages and shortcomings of Ionic, we finally chose it as our development environment. We could have one code for all platforms.

2.3.2. Firebase

In short, Firebase is a platform which allows to build web and mobile applications without server-side programming language. We can store users' data on its real-time database. With just a single API, the Firebase database provides both current value of the data and any updates to that data.

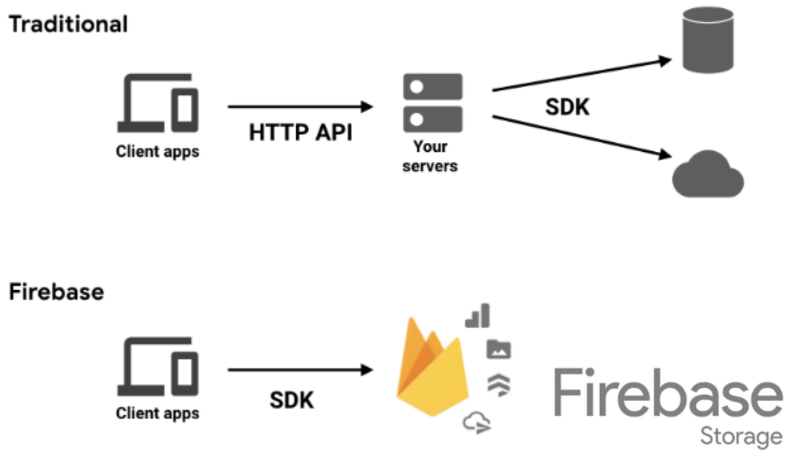


Figure 8: Comparison between traditional architecture and firebase architecture

Figure 8 shows two different configurations of app structures. The traditional structure of an application usually consists of at least three parts: an application front-end, a server and a database to ensure the services. But Firebase is a Backend-as-a-Service, known as **BaaS**, which integrates all the back-end services.

We decided to use Firebase because for a short-term project, it is usually strongly recommended to avoid a heavy back-end. That means we wanted to pay more attention to the front-end. Users are directly in face of the front-end and they don't care how we configured the back-end, so we wouldn't like to rewrite a back-end if we can do it more easily. Firebase was the solution.

2.4. Tools for image processing and 3D models

2.4.1. Images filters

2.4.1.1. Needs

The goal of the application is to let the user choosing a picture from its library to engrave it, imprint it or embroider it on its furniture. After having chosen a picture, the client needs to apply a filter which would change the picture so that it is suitable for engraving and can be saved as a ***.svg* file** (the needed format for laser-engraving or laser-cutting).

We needed to implement different filters to let customers choosing the one they prefer.

2.4.1.2. Methods & development

First, we have made a lot of researches online to know if some filters were already existing. We have found and selected nine filters. They are coded in JavaScript, this is useful because the application handled JavaScript language, so it is easiest to incorporate them.

We used Processing and Sublime Text software to code and adapt the filters. After having studied these nine filters, we have selected three of them which seemed to meet our client requirements. They were already turning images to black and white, which was needed for the .svg file.

2.4.1.3. Filters choice and customization

The first filter changes every pixel in a **** (kind of a backslash) and the size and the length of the backslash depends on the brightness of each pixel. At the beginning we had a lot of different sizes of **** but after having met Miss Bruyère we have decided to use only three sizes depending on three intervals of brightness.

Thanks to this filter we have been able to change the shape of \ to a ● and a ■, displayed in Figure 9. With these modifications we can have two more filters for our application.

*Figure 9: Filters with different shapes: **** (left), ● (middle), ■ (right).*

Moreover, we had to think about the space between each shape and the final size of the picture. In the case of laser-cutting through the entire layer of material, holes for ****, ● or ■ will be used for embroidery, so a needle must be able to go through it (min 1.5mm). The laser must cut those shapes and the interval between two holes must be strong enough to support the weight of the cutting and to not break when we sew on it.

After some discussion with our client, we have chosen four format sizes for cutting or engraving: A2, A3, A4, A5. There will also be three sizes of shape for each filter (to observe the differences of brightness). For engraving (meaning that the material is not cut through), we have added three more resolutions for each format (because there is no need for the shapes to be big enough for a needle).

If the user wants a high resolution, the size of the shapes will be smaller to have more shapes for each row and column.

The **second filter** draws random lines and the superposition of these lines makes the picture appear. We have selected this filter only for engraving, but we have had a problem, it can represent the picture only if there is a lot of contrast when we convert the picture in black and white. It will probably be integrated to the final application, maybe with a warning message saying that it needs a lot of contrast and it takes a lot of time to run.

However, to improve this filter, we managed to develop a program which modifies the contrast and the brightness before using the filter in the draw function. Moreover, we can inverse the brightness of each pixel to create kind of a negative for better results.

The **third filter** changes a picture in a pointillist painting, it can be used only for engraving, it alters randomly a pixel in a shade of grey point which corresponds to the brightness of this pixel. Based on the program of the first filter we can easily modify our program to create the four format sizes and save it.

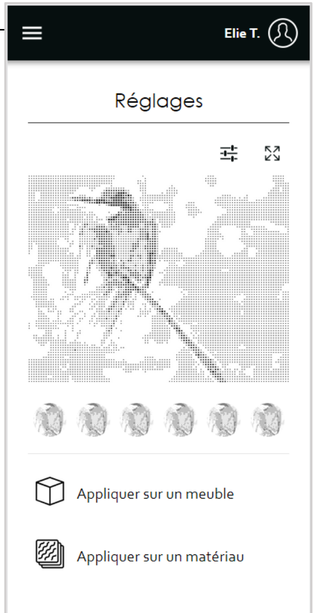
The rendering of these filters is shown in Result examples2.4.1.6.

2.4.1.4. Saving

One of the hard part of filters was saving the Javascript canvas in a .svg file. We spent a lot of time looking for functions and we finally found a way to do it: we had to add a Javascript SVG library to our filter, to declare our canvas as a SVG and to use the function save() when a button is pushed by a user.

2.4.1.5. Structure of the code for the filters with shapes

Here is the simplified structure of our Javascript file for each filter with the description of the main functions used.




```
//Variables
//Functions
function preload() {
    //Choosing the image to load
    //To fill a tab with as much images as sizes required
}

function setup() {
     //Setup the canvas regarding the image size
}

function draw() {
     //To apply the filter
}

function save_canvas() {
    //To save the canva in SVG
}

function change() {
    //To detect a change in buttons states (to have a new size)
    //To redraw the canva with new size
       redraw();
}
```

2.4.1.6. Result examples

Here are examples for the first filter with 3 different shapes, in A4 format with a middle resolution.

Figure 10: Original Image

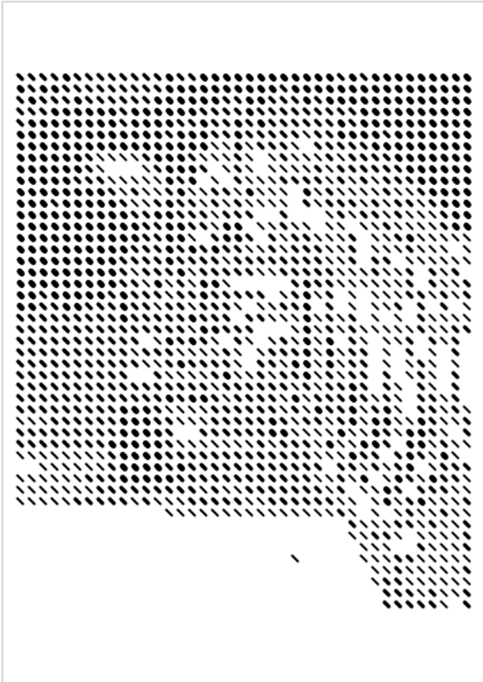


Figure 11: Filter with the \ shape in A4 format

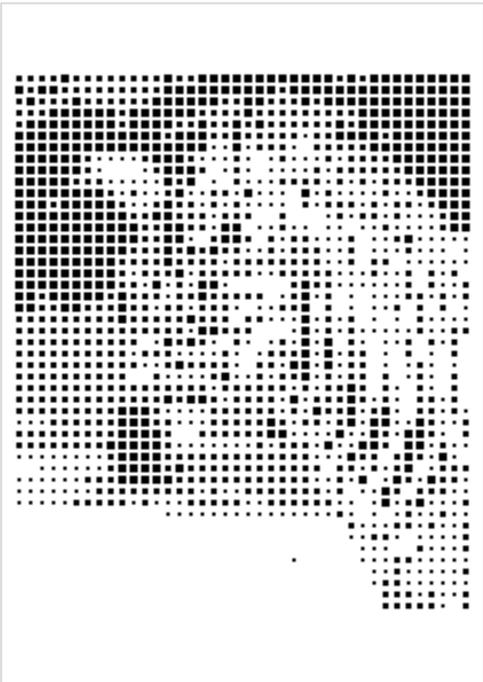


Figure 12: Filter with the ■ shape in A4 format

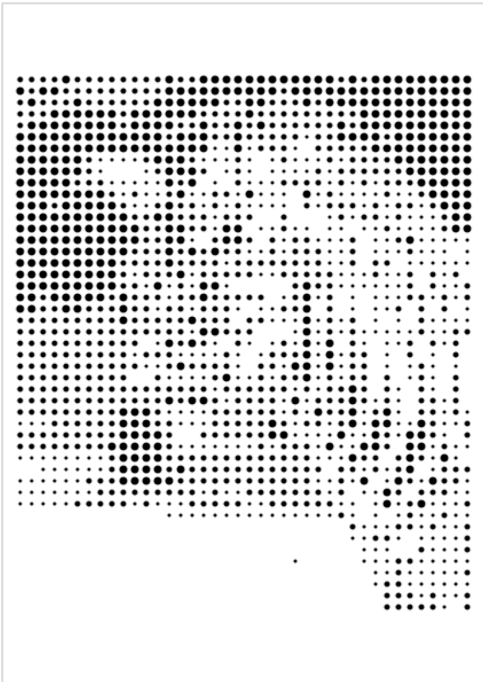


Figure 13: Filter with the ● shape in A4 format

We can also run the second and third filters to this picture to obtain other great designs, the user can choose its favorite.

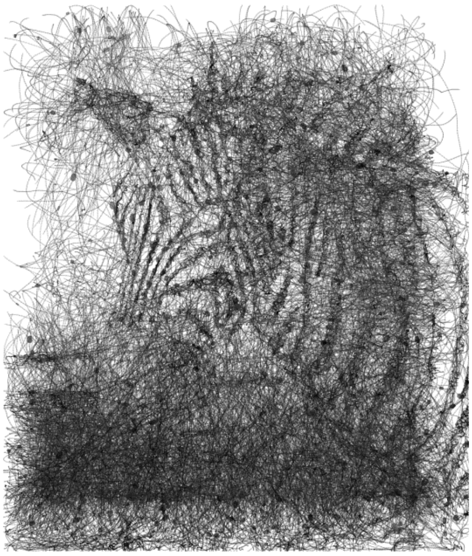


Figure 14: Filter with random lines (negative black and white)

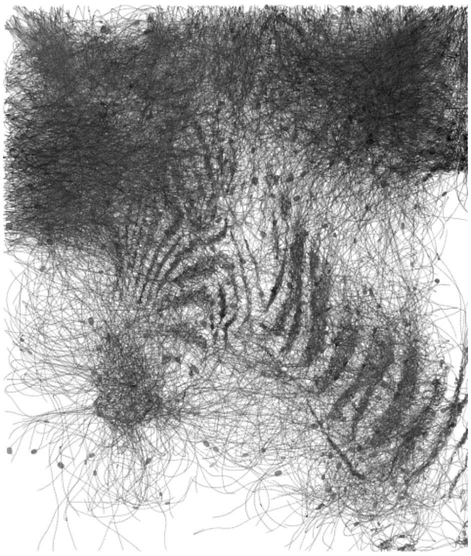


Figure 15: Filter with random lines (black and white)

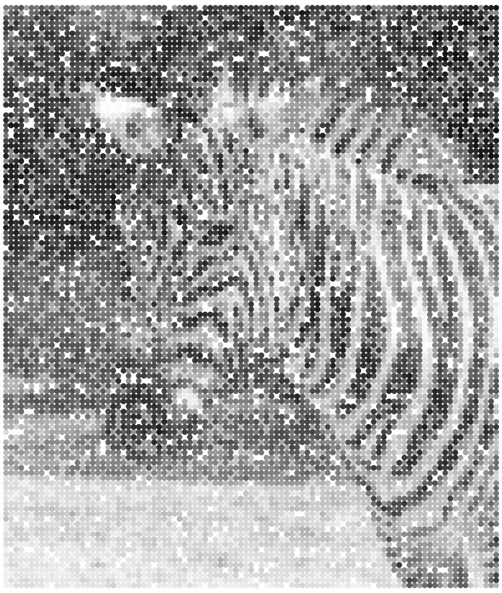


Figure 16: Pointillism style filter in A4 fomat

2.4.2. 3D models with Shape Diver

As our client, the Ultra Ordinaire company, is a studio which designs furniture in 3D, we need to manage all their 3D model with a special platform. We chose **ShapeDiver**. ShapeDiver automatically turns the parametric CAD files into interactive 3D models that can be easily accessed through any modern web browser.

In the shapediver.com website, designers upload their Grasshopper definitions and create interactive 3D models. Thanks to the ShapeDiver API, we could integrate the 3D visualization and modification interface in our application. By using our application, users can choose the parameters in the model and then ShapeDiver will store the parameters chosen by users of this model.

This platform is not free if we want to use it for commercial use. Our client will pay $99 per month to access API and all tools of the ShapeDiver plugin. During the development, we could use a basic account which was free for testing.

To use it, there are some steps. First, we should turn the products and its logic into an intelligent CAD model that contains everything. The Ultra Ordinaire company will do this part of job. Secondly, upload the files to ShapeDiver and configurate all the variations and features of the product. Then integrate it with our application. We will do this step. Then Ultra Ordinaire can find orders in the dashboard.

The figure below (Figure 17) shows an example of the usage of ShapeDiver. Our application has a similar interface.

Figure 17: Usage of ShapeDiver

2.5. Results

After three months of hard work, the application was finished. The following screenshots detail the user interface and some functions implemented in our app. We also added a capture of the database for one user (Figure 19: Firebase real-time databaseFigure 19).

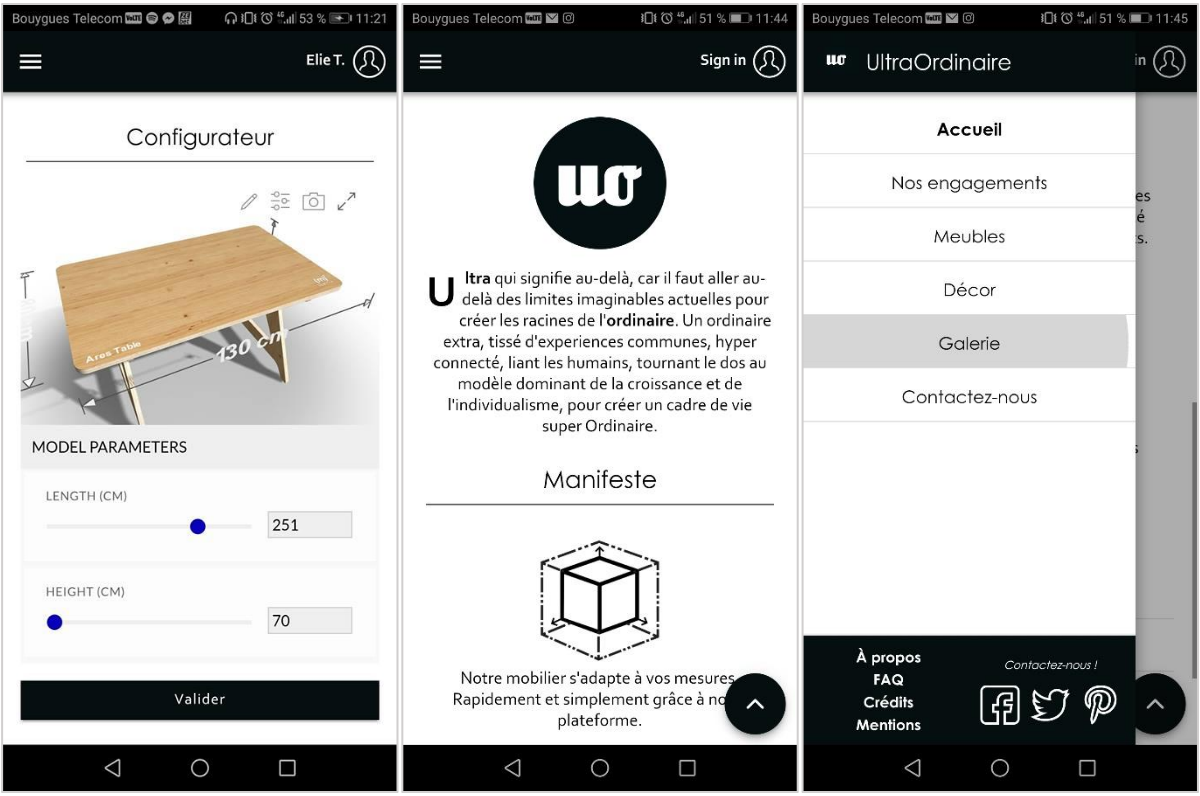


Figure 18: Screenshots of the final application

The first figure is the screen that allows the user to change the parameters of a furniture.

The second figure shows the main page of the application. At the left of the top, there is an icon for the menu. If we click this button, the menu will appear.

This third figure shows the structure of menu. We can find 5 columns, and when you click each item, you will enter each page.

At the top-right, we can see a silhouette of a person. With this button we have access to the login page and create an account.

More app screenshots are available at the end of this report.

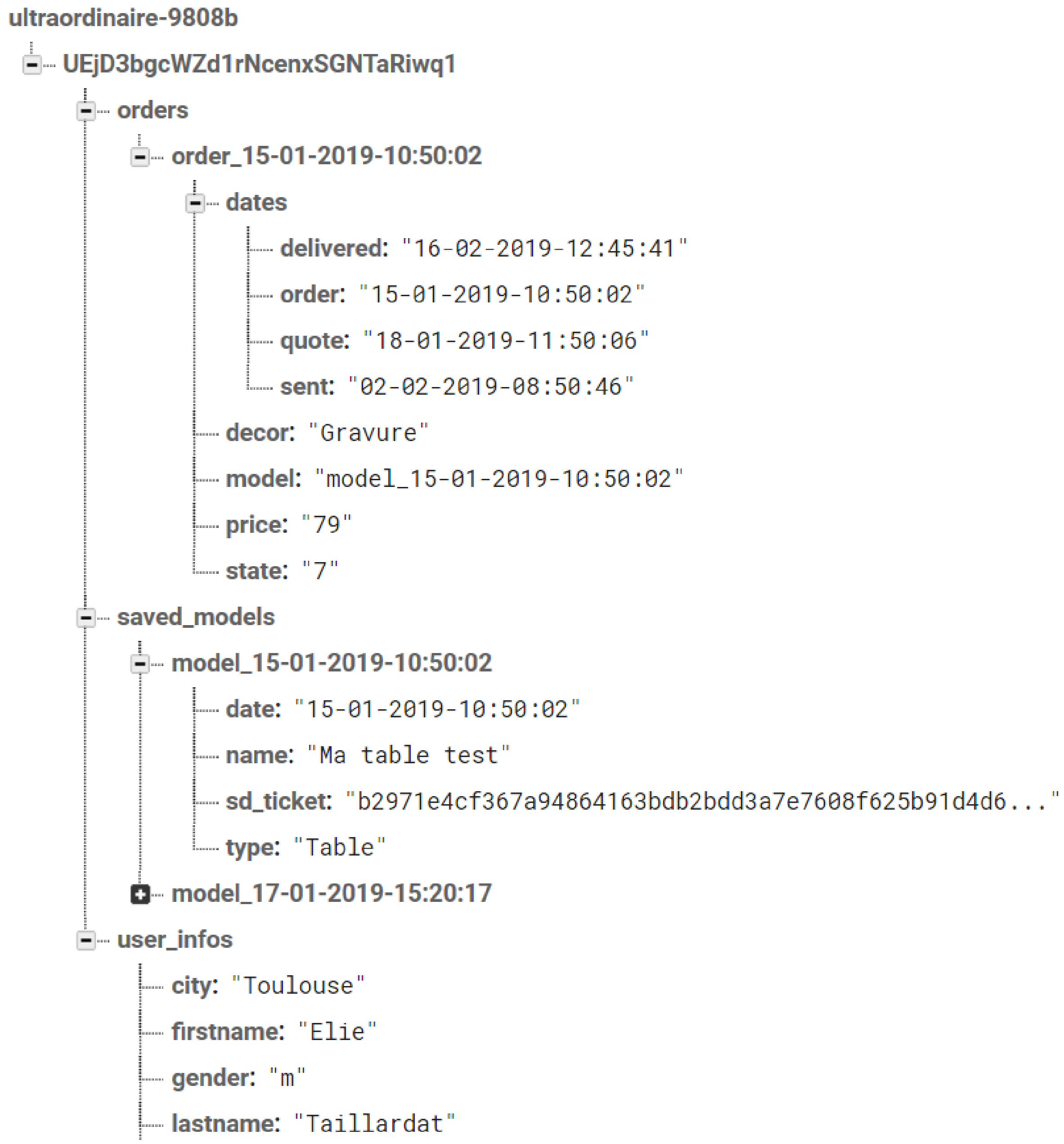


Figure 19: Firebase real-time database

2.6. Difficulties and improvements

2.6.1. Difficulties

Meanwhile our team encountered some difficulties during this project. Most of them were resolved at the end of the project but there are some that we continue thinking about.

The first difficulty occurred at the beginning: the choice of techniques. Our client, company Ultra Ordinaire, wanted to develop both android app and iOS app, as well as a website, but we only had 4 months and we still had other courses to do. This was a big scale of work and we risked not finishing all works. For this reason, we tried to find a technology which can run cross-platform so that with one code we run it anywhere. Unlike native apps, web apps are less effective but flexible enough. They meet our requirements so well, so we decided to use Ionic -- a powerful framework for developing web apps.

Although the requirements were clear at the beginning of the project, making a business process was not an easy job. After we finished the design of user interfaces, we started developing application with Ionic and firebase. With firebase, we didn't need to write a big back-end, but we still must manage the database and design the tables to store client data. We discussed the structure of orders and wrote down all the processes.

The ShapeDiver platform was also a challenge for us. It is even more difficult when we developed it with a test account. In this platform, there are three types of account: free account, account pro and account enterprise. As the name suggests, the free account is totally free, but we can only upload 3D model and have a common knowledge of what it is. Our aim is to use the API that this platform provides but now we didn't have a pro account to integrate in the project. We read the API documents which presents all the functions and parameters. After that we tried to use the platform. Finally, we overcame this difficulty.

2.6.2. Improvements

Until now, app part of this project is almost finished but we still have some improvements.

For the integration of ShapeDiver, we need an account of this platform to manage all the 3D models and add them in our application. But it costs at least $99 per month. For this reason, during the development we chose to use some test API to simulate the real situation. Now all data about the 3D model are just for testing so in further development, before publishing the apps to app stores, we need some more works to finish it totally.

After filtering the image, users would like to choose the position where to put their images. But the first version of our application doesn't provide this function. To improve the application performance and make users feel better, we can add this function in version 1.1.

3. The autonomous lamp project

3.1. Specifications

The second project has been defined to give us a more electronical knowledge regarding the Internet-of-Things.

For this lamp project, we had to build an interior lamp which has an autonomous energy supply and whose intensity varies with sunlight and usage. The requirements called for an on/off switch, a sensor to capture the light level in the room, and the automatic control of the lamp light level depending on the light level of the room. We should test the production, we could use the INSA's FabLab, and, if necessary, parts could be 3D-printed.

The shape and look of the lamp would depend on how we met the requirements mentioned above, but the following visual provided by our client gave an idea of what the lamp would look like.

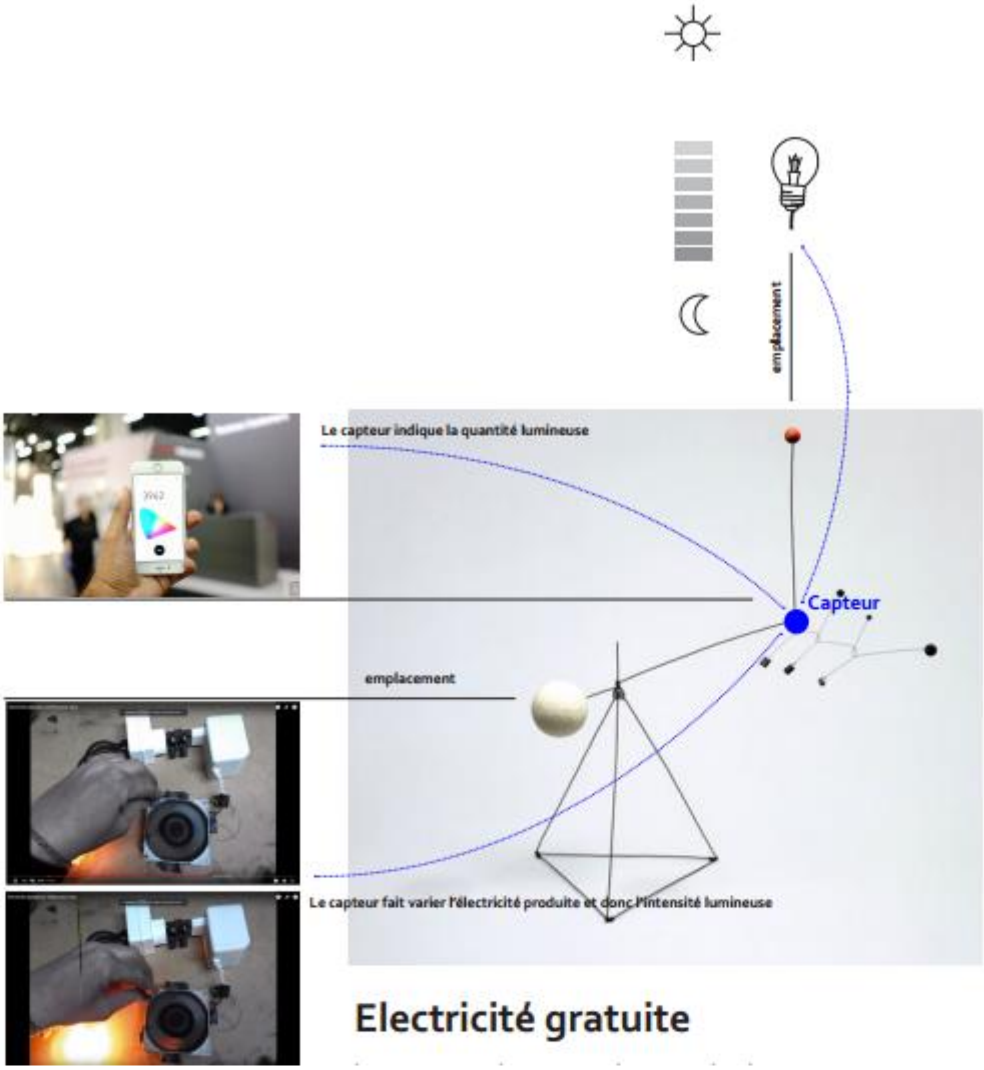


Figure 20: Possible design of the lamp

For this project, delivering a partial prototype and documentation on our work was enough. Indeed, it was a side project compared to the app project.

Deliverables were:

- Execution files for electricity production and global scheme
- Code with comments and a tested and working app if it has been developed

3.2. Planning of development

This project was in parallel with the app project. We dedicated two people to work on the lamp, Jonathan and Sophie since they come from AE and have some basis in electronics. At the end of the project, when it became more important to finish the app than the lamp, only one person has been working on the lamp project, first, only Jonathan then at the very end, only Sophie.

We used Trello to plan our tasks and, as previously said, we had weekly meetings with our client.

We dedicated the first three weeks of the project to investigate and find an energy source.

Then, we dedicated a month to order, experiment and build the prototype. We knew the planning was short and we had another project going on, so the IoT and app part was not mandatory, and we dropped it at the end of the project.

3.3. Defining the prototype

3.3.1. State-of-the-art of available energy sources in a house

The first step for this prototype was to define our energy source. Our client gave us the idea of producing electricity with magnetic energy, using only magnets and a fan, like in this video: https://www.youtube.com/watch?v=6sAJzjJ6ujE. However, after experiments and researches, we found that it was fake. One of the various reasons was that these fans are motors and cannot be used as generators. Even if we could use generators that converts mechanical energy to electrical energy, the magnets used for the rotation would reach a stability point, so the fan would stop turning.

So, we looked for possible sources of energy. We did a state-of-the-art to deliver to our client.

We started by quantifying the power needed for different light sources. We found that LED was the best technology to save energy. However, LEDs for lighting a room properly need a power of approximately 5W. This may be too much for the energy sources we have (detailed below). Thus, we also searched for LEDs that consume less. We found some that need around $60\ mW$ of power, but with a much lower intensity. After discussing with our client, we decided that the usage of the lamp (bright light, atmospheric light, pilot light, …) would depend on the light level we could achieve with the energy source.

After finding the best light emitting technology, we searched for possible energy sources. We brainstormed and searched for energy waste happening in a house, and we investigated how to use these sources.

3.3.1.1. Solar Energy

Of course, light from the sun through the windows was a possible source of energy, using solar panels to harvest it.

By testing cheap solar panels of $13 * 6.5\ cm$ available at INSA's FabLab, we could produce $300\ mA$ at $0.7V$ under lamp light. This leads to a power

$$P_{solar} = 300\ mA * 0.7V = 210\ mW$$

We know that by placing solar panels in series/parallel, we can increase the voltage/current respectively and get more power. So, this is a suitable source of energy for our application.

With the goal to propose something innovative to our client, we looked for unusual ideas using solar panels. We found an effective technique that concentrates the sun rays using lenses or spheres filled with water. In the Rawlemon project pictured in Figure 21, they associated this idea with a mount that follows the sun rotation and a thermic solar panel. This has a much better performance than classic solar panels [6].

Figure 21: The Rawlemon, created by the architect André Broessel that concentrates 10 000 times the solar rays

3.3.1.2. Temperature differences

In a house, there is a lot of energy wasted in the form of heat: computers, fridges, water from showers, pipes, or heat from the sun. Using thermoelectric generators (TEGs), it is possible to produce electricity from a temperature difference.

The principle of TEGs is the Seebeck effect: a temperature difference is converted in electricity at the junction of two different materials. The inverse effect is known as Peltier effect, when a difference of potential causes the junction to heat.

TEGs are made with P-doped and N-doped semiconductors, thermally connected in parallel but electrically connected in series (Figure 22) [7]. When a heat difference is applied at the junction of these semiconductors, a potential difference is produced at the ends of the semiconductors.

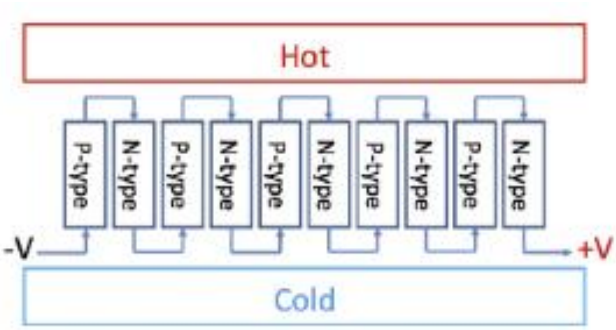


Figure 22: Principle of thermoelectric generators

In this report, the term “Peltier Module” will refer to TEGs, as they are built the same way, but used differently (the Peltier effect produces a temperature difference from a potential difference). A typical TEG is shown on Figure 23.

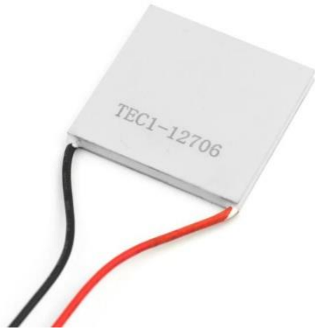


Figure 23: A TEG or Peltier module

TEGs can produce between $10\ mV/K$ and $50\ mV/K$ depending on the number of couple of junctions.

In a house, we can find a hot source with a five to ten degrees difference with the room temperature, and we found some applications using Peltier Modules to light a LED from body heat (Figure 24), meaning Peltier modules could be a suitable solution [8]–[10].

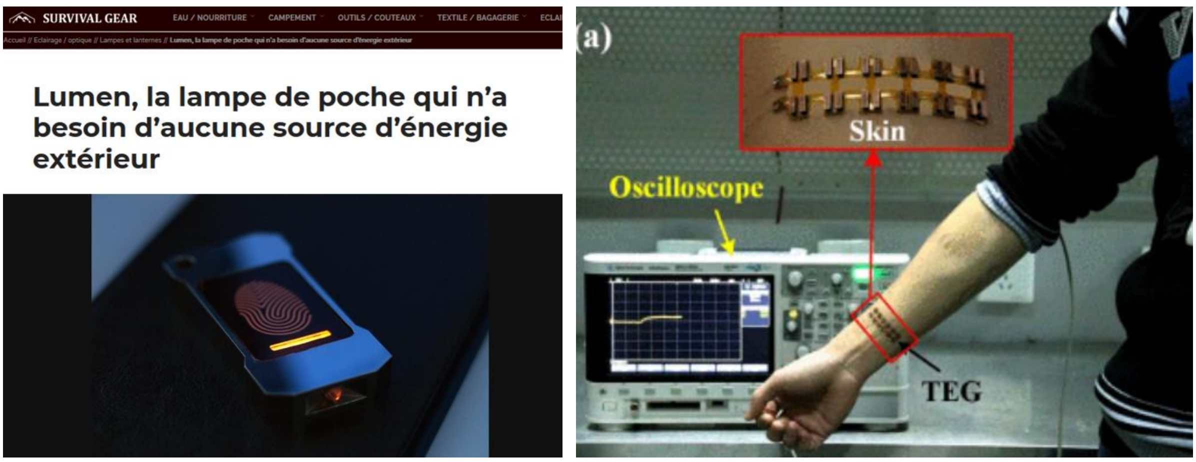


Figure 24: Two different possible applications of TEGs

3.3.1.3. Mechanical energy

When a door is slammed, windows are closed or people walk, energy is produced by the movement. It is possible to collect this energy using piezo-electric generators.

However, in a private home, these movement are not made continuously. Even though we found that we could harvest around $1W$ of power from swinging doors [11], [12], it happens so little that it is not suitable for a lighting application.

Using piezo-electric generator to harvest energy from people walking is possible, it has already been done in some night-clubs. However, it implied installing a whole new floor, and the idea was abandoned very quickly after discussing with our client.

Also, it is possible to harvest mechanical energy with a manual dynamo, meaning that people would produce their energy manually. Dynamo flashlights are commercialized so energy produced from dynamo is enough to light a LED.

Once we searched for energy sources and their suitability for our project, we discussed with our client to choose one that suits best for the project.

3.3.2. Choosing the energy source and defining a prototype

We presented our solutions at the second meeting with our client. The two solutions selected with our client were:

- the Rawlemon principle
- the thermoelectric generators

To choose between both, we did further experimentations.

3.3.2.1. Rawlemon test

The Rawlemon solution was first tested. Indeed, solar panels were the “easiest” way for us to collect energy since solar panels have a good performance (compared to other energy harvesters) and we had already studied solar panels during our studies. Why not using just solar panels then? Our client did not want “simple” solar panels. Associated with a sphere like in the Rawlemon example, it gave a more poetic aspect to the energy production that our client preferred.

We started by testing the Rawlemon principle using a very small solar panel and a plastic light bulb filled with water. On a cloudy day, we first measured the voltage of a simple solar panel. Then, we measured the voltage of solar panel with light concentrated at its surface with the light bulb filled with water. We obtained the results on the table below.

Table 1: Comparison of the voltage of one solar panel on a cloudy day, with or without light concentration

	Voltage (simple solar panel)	Voltage (light concentration)
Voltage of one solar panel	$515\ mV$	$530\ mV$

We could see a small improvement of 3% on the voltage thanks to the concentration of the light on the solar panel.

Then, the feasibility of the solution has been discussed with our client. For a real product, we would have needed a sealed glass sphere with purified water and no air. If the sphere was not sealed, water would evaporate or become dirty. To our client, it seemed too complicated and costly to produce this sealed glass filled with water, especially before the end of the project mid-January. So, at the third meeting, we abandoned the idea of the Rawlemon and chose to focus on the thermoelectric generators.

3.3.2.2. Thermoelectric generators: prototype

The final choice was the thermoelectric generators. It seemed to us that the most promising source of heat in a house was a computer: the processor can heat very quickly at around 50-60°C. The computer box heats as well and could be used as the hot source. To keep the other side of the Peltier module fresh, we would add a dissipator and we had the idea of putting a fan that a human could turn to give fresh air.

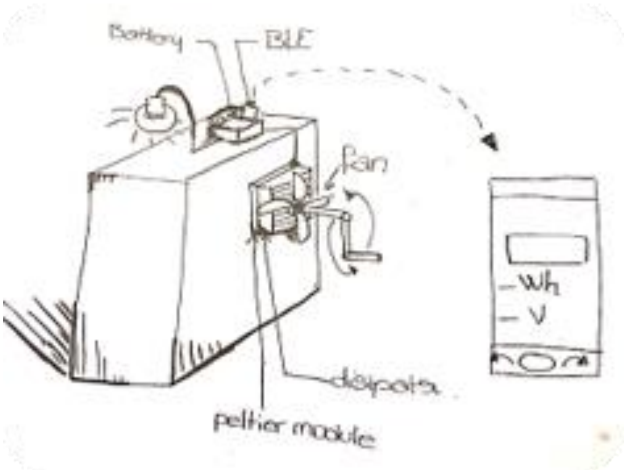


Figure 25: First idea of prototype

To add some IoT to this prototype, we thought about connecting the lamp to the smartphone using Bluetooth Low Energy (BLE). It is a local, low power way of communication that would suit the usage.

Since the IoT part is the most facultative part of the prototype, we first focused on the energy harvesting to light the lamp. Furthermore, at that stage, we did not make further experiments to know how much power we can harvest from Peltier modules at a rather low temperature difference. To keep things simple, we ordered the following parts for experimenting our solution:

- White LED, $2.3\ V, avg.\ 50\ mA$ for a light level of $1650\ mcd$ that is good for a small light. The power needed to light the LED is shown on the table below
- Red LED, $1.6\ V$ that works from $1\ mA$ (light level of $3\ mcd$) but we used an average of $20\ mA$ for our tests. The power needed to light the LED is shown below.

Table 2: LEDs power

LED type	Power
White LED	$P_{white\ LED} = 2.3 * 50 = 115\ mW$
Red LED	Average power: $P_{red\ LED\_avg} = 1.6 * 20 = 32\ mW$ Minimum power: $P_{red\ LED\_min} = 1.6 * 1 = 1.6\ mW$

- 5 TEGs with ceramic coating, middle quality, and 5 dissipators in aluminum of the same size (40*40 mm), with a thermal resistance of 3.5 K/W.
- Supercapacitors of $120\ F$ and $220\ F$ to store energy. Supercapacitors allow a higher number of cycles of charge/discharge than Li-ion or other batteries. We decided to buy two sizes for testing. The capacitances were chosen to provide several minutes of light with the white LED using the following equations:

The voltage across a capacitor at any given time for a RC circuit (like we used) is [13]

$$V(t) = V_{init} * e^{-t/RC}$$

Rearranging the terms, we can express the discharge time:

$$t = -\log\left(\frac{V}{V_{init}}\right) * RC$$

With:

- V (or $V(t)$) the voltage across the capacitor at any time, that we want equal to the LED voltage (Volts)
- V_{init} the start voltage of the supercapacitor, $V_{init} = 2.7\ V$ for both capacitors (Volts)
- R the resistive load, $R = \frac{V_{init}}{I_{load}}$ (Ohms)
- C the capacitance of the capacitor (Farads)

When applied to our LEDs and capacitors, it gives the following discharge times:

Table 3: Theoretical time duration of the supercapacitors depending on the load (LEDs with a resistance in series) (RC circuit)

	Red LED (test LED)	White LED (final LED)
Minimum Load Voltage V	$1.6\ V$	$2.3\ V$
Average Load Current I_{load} (maximum current to deliver)	$20\ mA$	$50\ mA$
Resistive Load R (calculated)	$135\ \Omega$	$54\ \Omega$
Discharge time of the $120\ F$ supercapacitor	$\mathbf{1.80\ h}$	$\mathbf{14.4\ min}$
Discharge time of the $220\ F$ super capacitor	$\mathbf{3.32\ h}$	$\mathbf{27.1\ min}$

We see that using the $220F$ supercapacitor and the white LED, the light can be on for $27.1\ min$. This duration is not ideal, but it is enough for our application. The calculations also showed that the white LED consumes a lot of energy compared to the red one.

Now that we have our material, we can start experimenting our solution.

3.4. Characterization of the Peltier modules

Our first idea of circuit is to connect directly the LED to the TEG. Indeed, a TEG acts as a DC voltage source in series with an equivalent resistance (Figure 26). The open circuit voltage is proportional to the temperature difference applied on the sides of the TEG.

The internal resistance of our TEGs was $1.5\ \Omega\ \pm 10\%$.

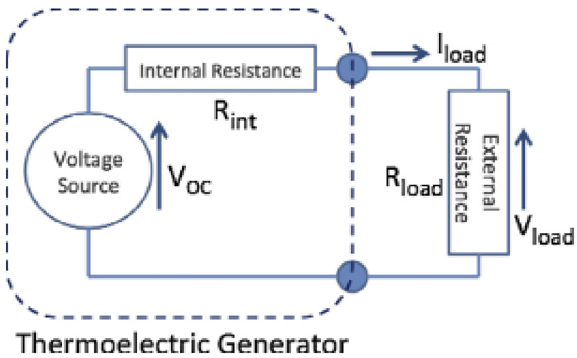


Figure 26: Electrical model of a TEG [7]

3.4.1. First testing: 1 module with a resistive load

We wanted to have an idea of the power we can achieve using one TEG.

For this experiment, we placed a cup of hot water on the top of the TEG. We connected a resistive load of $1.2\ \Omega$ to measure a current. Since the internal resistance of the TEG is $1.5\ \Omega\ \pm 10\%$, we consider we have impedance matching, so the power is maximal with some uncertainties (we reach the Maximum Power Point). The current and the temperature are measured with multimeters (ITC-921) and the voltage with an oscilloscope (KEYSIGHT DSOX1102G).

Table 4: Power of a TEG with a 1.2 ohms load

Temperature difference	Voltage (mV)	Current (mA)	Power (mW)
8	14.5	14.7	0.213
6	10.4	10.4	0.108
3	6.97	6.98	0.048
2	3.47	3.54	0.012
1	1.34	1.49	0.002

We could see that there was enough current to light the red LED (minimum intensity at $1\ mA$). However, the voltage was too low compared to the needed voltage of the red LED ($1.6\ V$). We could have connected TEGs in series to increase the voltage. However, even by connecting our five TEGs in series, we could only have $V = 14.5 * 5 = 72.5\ mV$ at 8°C of temperature difference.

So, we tried to define the minimum temperature difference to light our red LED.

3.4.2. Second testing: 1 module with a red LED

To light the red LED, we need the open-circuit voltage of the TEG to be between 1.6 and $1.8\ V$. The current must not exceed $300\ mA$.

Using one single Peltier module with no load, it is impossible to reach $1.6\ V$. Even with a difference of $110°C$, the voltage obtained is around $1.2\ V$ as displayed on Figure 27 [14].

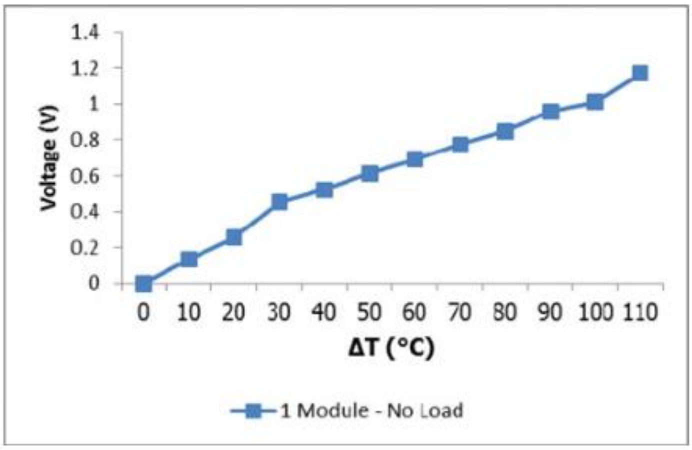


Figure 27: Voltage depending on the temperature difference with 1 TEG and no load (open-circuit voltage)

3.4.3. Third testing: 4 modules in series with a red LED

So, to increase the voltage, we connected Peltier modules in series, and we connected the red LED at the ends. The circuit schematic is on Figure 28 (the LED model is different from the one we use in real life). In series, we sum the voltages and the internal resistances of each TEG.

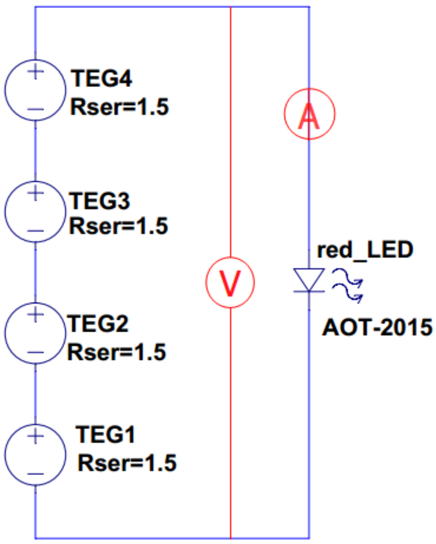


Figure 28: Four TEGs in series connected to a red LED

To find the necessary temperature to light a LED with 4 Peltier modules in series, we heated the hot side of the Peltier modules with a hair dryer, and the dissipators of the cold sides were in ice. During the experiment, we measured the temperature on both sides. We obtained the following results:

- With a temperature difference of around $30°C$, we could light the LED with a voltage of $1.6\ V$ at $5\ mA$ (Figure 29).
- For a more shining light, with a temperature difference of around $40°C$, we could obtain a voltage of $1.78\ V$ at $18\ mA$. The higher current gave more light intensity however, we should be careful to keep the voltage under $1.8\ V$ to preserve the LED.

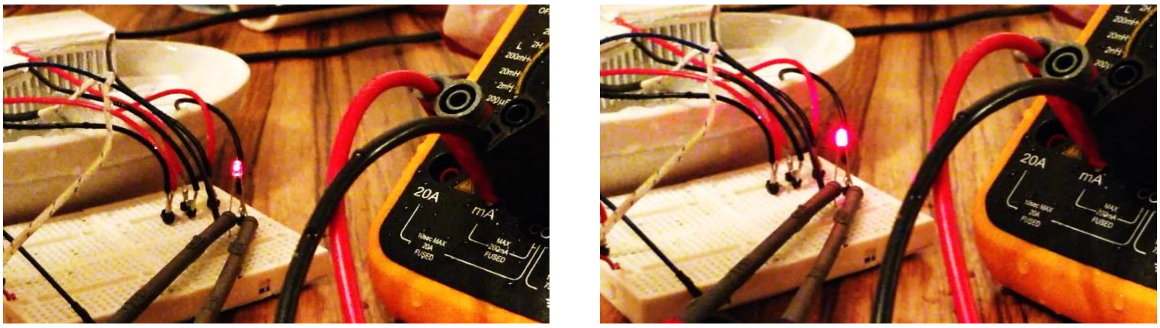


Figure 29: LED intensity, LEFT: @ 5mA (1.6V) and RIGHT: @ 18mA (1.78V)

In practice, it may be possible to keep a $30°C$ temperature difference by placing a computer processor near the hot side and ice on the cold side of the TEG (that should be changed when melted).

3.4.4. Critical analysis and conclusions

So, to light a red LED, having a temperature difference of $30°C$ between both sides of the TEGs is indispensable, otherwise more TEGs should be added to increase the voltage.

In our case, having a good temperature difference may be difficult because the sides of a TEG would eventually reach a temperature equilibrium and hot sources in a house are hard to find. Furthermore, connecting a dozen TEGs in series would be very costly (each TEG costing around 20$, it would lead to a product of at least 240$).

So, we searched for other solutions, presented in the following part.

3.5. Energy harvesters

Our red LED needs a power of $32\ mW$ at $20\ mA$. If the LED is lit up for half an hour (30 minutes) out of a day (1440 minutes), the average power needed in a day is $32\ mW * \frac{30}{1440} = 0.67\ mW$.

For 30 minutes of light with the white LED, the average power needed in a day is $115\ mW * \frac{30}{1440} = 2.40\ mW$.

It looks like something achievable when harvesting energy with TEGs. All we need is a power management solution that could harvest energy from very low voltages, consumes very little current to manage the accumulated energy, and produces regulated output voltages.[15]

This solution takes the form of energy harvesting chips like the LTC3108 from Linear Technology [16], the BQ25570 from Texas Instruments [17], or the SPV1050 from STMicroelectronics [18].

These solutions can provide energy harvesting from a voltage as low as 20 mV (LTC3108) or 100 mV (BQ25570). The power can be stored in a storage element, like the capacitors we have. Since the LED will not be lit up all day long, and since our TEGs may produce energy all day long (for example when they are placed at the back of the fridge), energy can be stored in the capacitor all day long to deliver the energy at higher voltage to light the LED for a short period of time.

The following figure (Figure 30) shows a possible application of the LTC3108. A TEG is used to power a microprocessor continuously (V_{LDO}) and store energy to transmit sensor data through RF (V_{OUT}) every $500\ ms$.

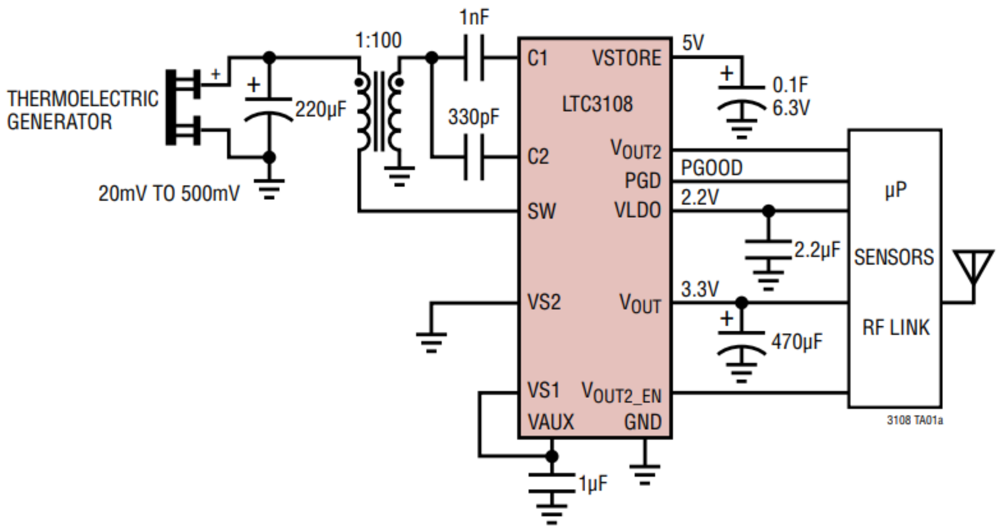


Figure 30: Wireless Remote Sensor Application powered from a Peltier Cell with the LTC3108, from the LTC3108 datasheet

However, we were short in time and could not investigate this solution deeper. The LTC3108 may not be the most suitable chip but the principle is promising and could be a solution.

3.6. Conclusions and future improvements

At the beginning of the project, we spent some time finding a source of energy and ordered very quickly the components to respect the orders deadline.

For the moment, our solution consists of maintaining enough temperature difference on the ends of Peltier modules in series. This provides enough voltage to light a red LED. This solution is limited by the fact that temperature tends to equilibrate at both sides of the Peltier modules. To be able to produce energy at lower temperature difference, we started to investigate the energy harvesting chips solution. More work and experiments can be done on this solution. Also, the IoT part of the project has been left aside. Indeed, with no more energy, it seemed too energy consuming to add connectivity to the LED. However, we could add an external battery that would only be used for the wireless application.

To conclude, finding an autonomous energy source that provides enough energy for a lamp is a real challenge on which researchers and industrials are working, and we realized that the needed energy to light a white LED may seem very high compared to the energy source.

Conclusion

This project has run during our last semester at INSA. We could put our skills in the service of the independent, architecture-design Ultra Ordinaire company in a challenging and creative environment.

Through weekly meetings and Agile organization, we could work on two projects.

The first and main one, the furniture customization app, has been realized with the Ionic and Firebase software to allow for cross-platform development and simple back-end design. We customized open-source filters to convert pictures to suitable images for laser-cutting and engraving. The app front and back-end has been entirely realized by the end of the project, with minor needed improvements.

The second project on the autonomous lamp started with a state-of-the-art of energy sources in a house. We chose to use thermal energy and defined the use conditions to light a LED with thermoelectric generators. Since the power produced at low temperature difference is low compared to the energy needed to light a LED, the energy-harvesters solution has been discussed but not experimented.

During this project, we worked with people from the architecture and design field, who opened our mind from the engineering field to new perspectives on how technologies can be used.

It has also been rewarding to answer to a practical need from a real client. We felt invested and responsible. The regular meetings with our client have been a very good point to keep moving forward on the projects. The presence of Jérémie Grisolia has been really appreciated as the link and mediator between the student and client worlds.

In the end, we have learnt new technological skills on app development, image processing, 3D modelling and the harvest of energy, as well as soft skills on team and project management. Those soft skills have also been enhanced by the ISS cursus and its focus on innovation.

We could build mutual trust with our client that, through app development and maintenance, may lead to further collaboration.

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Team abstracts

Agathe

Our team was tasked with developing two projects for Ultra Ordinaire, a furniture design association. The first is an application for personalizing furniture. The second is making a prototype of an autonomous lamp. The application permits to change the size of the desk and change the junction, moreover it permits to choose one picture, add a filter on it and engrave it on a desk or cutting its shape on the desk. For that we need to learn Angular coding and use Ionic to create an cross-platform application. Moreover, we try to make prototype of the lamp thanks to a Peltier Module and a dissipator to make a lamp based on unused energy of the house. We meet our client every week, so we can focus on tasks weeks per weeks and make the project evolved with time but at the end we have to give her a functional application and prototype.

Keywords: *energy, creativity, wood, desk, difference, Peltier Module, energy exchange*

Guangjie

Ultra Ordinaire company wants to develop a cross-platform application to simplify the processes of ordering a self-style furniture, as well as finding a prototype for the power of lamps. We used Ionic and Firebase to configure this application and waterfall model was also mentioned. To filter images and manage 3D models, a lot of filters in JavaScript were downloaded and modified to situate this project, ShapeDiver was perfectly integrated in the application too. For the lamp, we choose the Thermoelectric cooling, or we can say, a Peltier module to help produce electricity. As a result, a complete application was developed. Users can choose the parameters of their own furniture and also filter the images that they want to sculpture at the surface of furniture. They send orders directly with our application. For the lamp we provided a prototype of the use of Peltier module and its capacities. At the end of these project, we submitted a working application and a prototype for power of lamps.

Keywords: *image filter, ShapeDiver, Peltier module, lamp power*

Sophie

With the omnipresence of new technologies in daily life, designers are incited to integrate electronics and computer science in their creations. We worked with a design company, Ultra Ordinaire, mainly to develop an app to customize furniture, to adapt its size and to decorate it with the user's own images. We also worked on building an interior lamp with an autonomous energy supply. To build a crossed-platform app, we used Ionic and Angular, and Firebase for the database. To manipulate 3D models, we integrated the Shape Diver API. For the lamp project, we did a state-of-the-art of energy sources in a house and characterized the energy production of thermoelectric generators (TEGs) to apply it to light a LED. The app featured user accounts management, 3D-models management, image processing with original filters, image converting for laser-cutting, and orders management. The end-user can visualize, manipulate and modify 3D models of furniture, choose to engrave or cut any image to decorate the furniture, follow his/her orders and save a wish list. For the lamp, four thermoelectric generators were associated in series to light a red LED. The temperature difference condition was defined experimentally. Solutions with off-the-shelf energy harvesters were investigated and evaluated. The app is developed and functional, it only needs minor improvements before being published. At the scale of the house, the use of thermoelectric is possible to light red LEDs for a short period of time.

Keywords: *thermoelectric generators, ShapeDiver, Ionic, image processing, laser-cutting*

Elie

UltraOrdinaire has the deep conviction to allow people developing their own creativity, inherently linked to materials and volumes. The objective: create a cross-platform application to build custom furniture models, with decoration engraving or imprinting after performing filter functions on personal pictures, and thus create a unique piece of work. Similarly, the autonomous lamp project wants to mix energy solving questions and architecture, with a design based on the technology. For main app project, we used powerful tools such as Ionic (based on Angular) and Firebase database to build a perfectly reliable app, with reusable pieces of code. Several filters have been coded based on image processing in JavaScript to truly customize user photos, and the API ShapeDiver was used to implement furniture 3D models with unique parameters. To build the lamp prototype, a pertinent state-of-the-art has been established, and finally Peltier modules have been used to generate electricity from heat loss sources and temperature gradients. The app allows user data management (sign-up/sign-in, settings, information, wish list, deliveries, historic of creation…), and the setup of 3D models and filter processes with various options. The prototype of the creative lamp is able to power a LED with four modules wired in series, and pertinent locations in the house to use this solution are reviewed (windows, parts of the floor…). Small improvements are needed within the application, but the simple process is doable by any user. The lamp utilization demands further research, but a complete report has been made with results and avenues.

Keywords*: Ionic, Angular, cross-platform app, Android, iOS, Firebase, ShapeDiver, filters, image/photo processing, JavaScript, Agile, state-of-the-art, Peltier module, energy savings, creativity, customization*

Jonathan

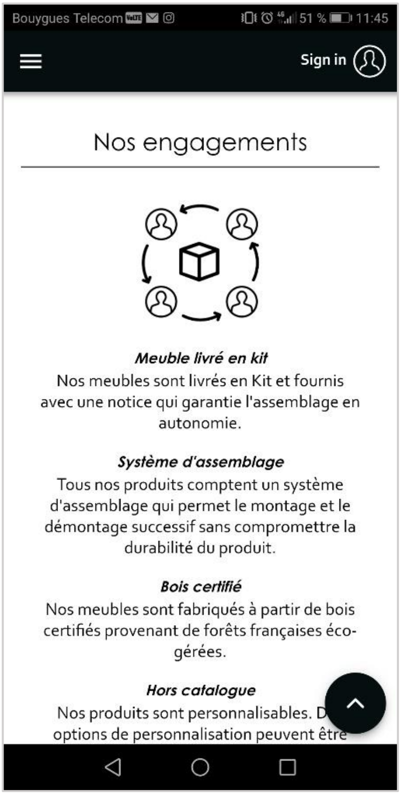
It is important to feel comfortable at home. This report gives you a preview of an application created for Ultra Ordinaire company which allows customers to design furniture. Energy is a problem, a lamp with an autonomous source of energy would be great. Regarding the app, the main concern was choosing a development environment compatible with both applications (iOS and Android) and website: Ionic, a complete environment based on Angular, allowing to use only one code for everything. For the database (user data and quotes) we use Firebase. We can upload an image to draw it (engraving or cutting) on furniture, using filters coded in Javascript (Processing). Finally, we use ShapeDiver API to display 3D-models and give the possibility to change sizes. Regarding the lamp, we have written a state-of-the-art giving the possible sources of energy. We developed one idea: to retrieve the thermal energy lost in our houses (from battery computers, …) using Peltier modules. The results for the two projects are pretty good, we developed an intuitive application. All actors (client,

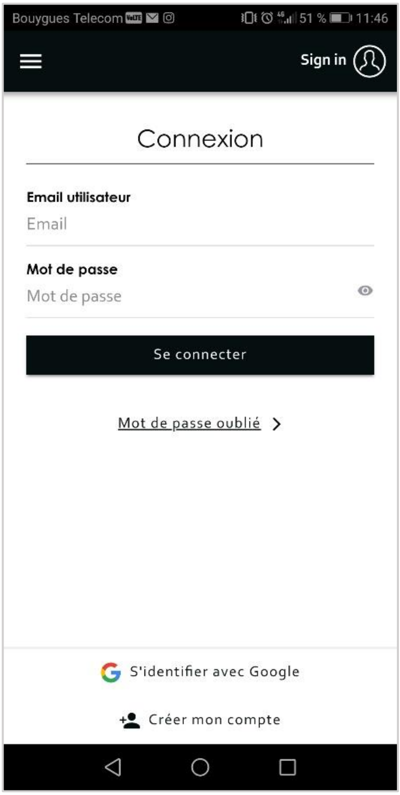
customers and companies) can use it or retrieve ready-to-use data. It is also available as a website, presents a login interface and has already five filters running. For the lamp, a prototype is available, turning on a LED (putting the prototype on a heat source). To conclude, this report is about two projects, one application that we have entirely developed and that is ready-to-use and one prototype, researches about it and other solutions to create an autonomous lamp.

Keywords: *autonomous energy, lamp, IoT, application, website, furniture design, Ionic, Processing, image filters, Firebase, Shape Diver, Peltier Module*

Appendices

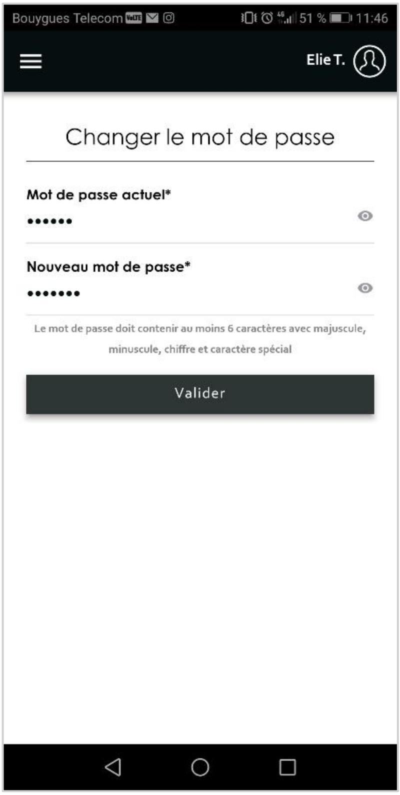
A1. App screenshots





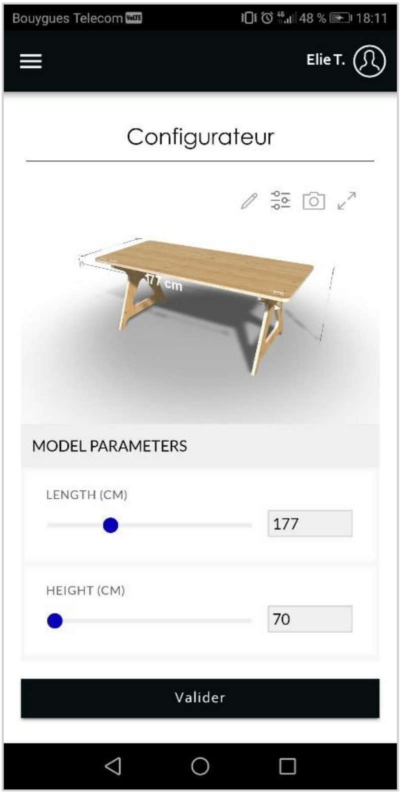

Bouygues Telecom
51 % 11:45
Elie T.
Bonjour Elie
Suivi de mes créations
Historique
Informations utilisateur
Changer le mot de passe
Déconnexion


Bouygues Telecom
51 % 11:46
Elie T.
Informations utilisateur
Nom*
Taillardat
Prénom*
Elie
Genre*
Homme
Adresse*
12 rue Marc Laffargue
Complément
31400
Toulouse
Téléphone*
+33 6 95 42 75 64
Email*
elie@test.fr
Votre mot de passe


Bouygues Telecom
51 % 11:46
Elie T.
Changer le mot de passe
Mot de passe actuel*
••••••
Nouveau mot de passe*
•••••••
Le mot de passe doit contenir au moins 6 caractères avec majuscule, minuscule, chiffre et caractère spécial
Valider


Bouygues Telecom
51 % 11:47
Sign in
Choisir une image pour créer une composition
Activer mon appareil photo
Choisir une photo de ma bibliothèque
Choisir une photo dans la base de donnée


Bouygues Telecom
50 % 11:49
Elie T.
Mes envies
TABLE
Cadeau de Elie
Date de création: 11-12-2018
TABLE
test 2
Date de création: 12-01-2019
TABLE
test table
Date de création: 12-01-2019


Bouygues Telecom
48 % 18:11
Elie T.
Configurateur
MODEL PARAMETERS
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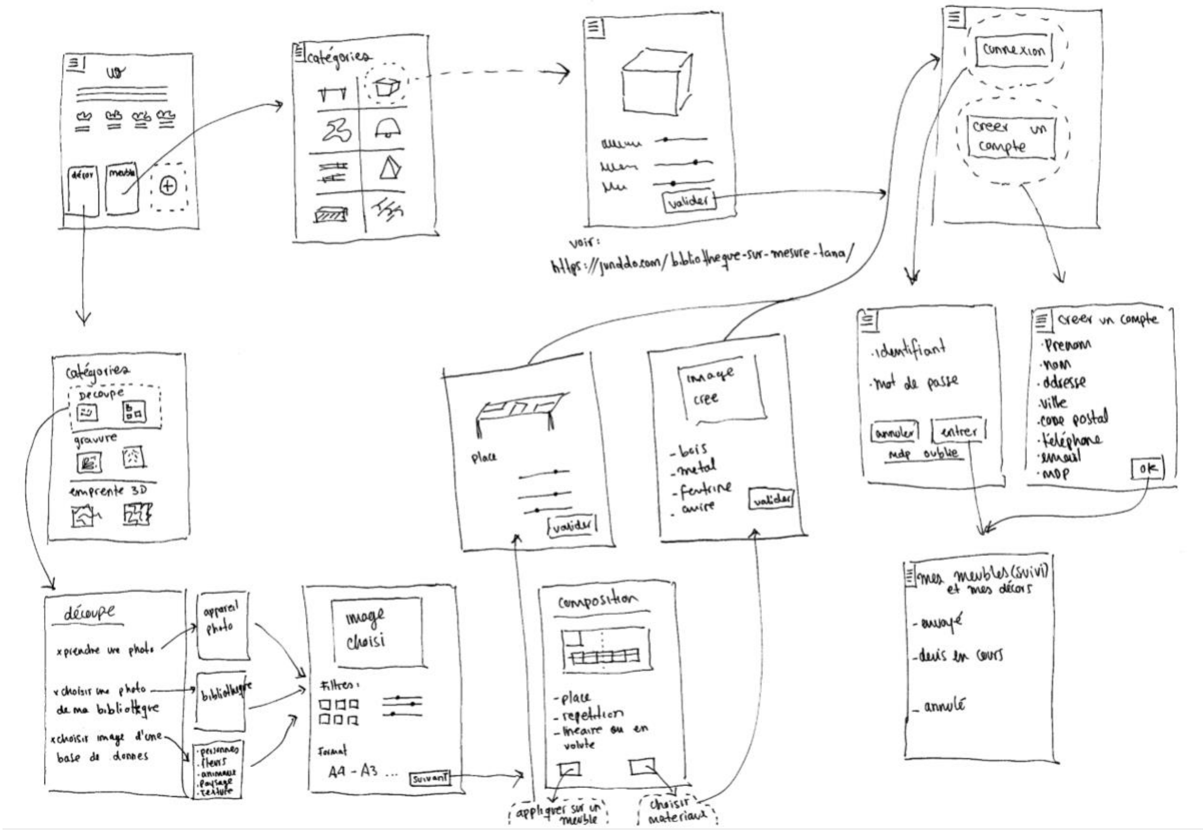
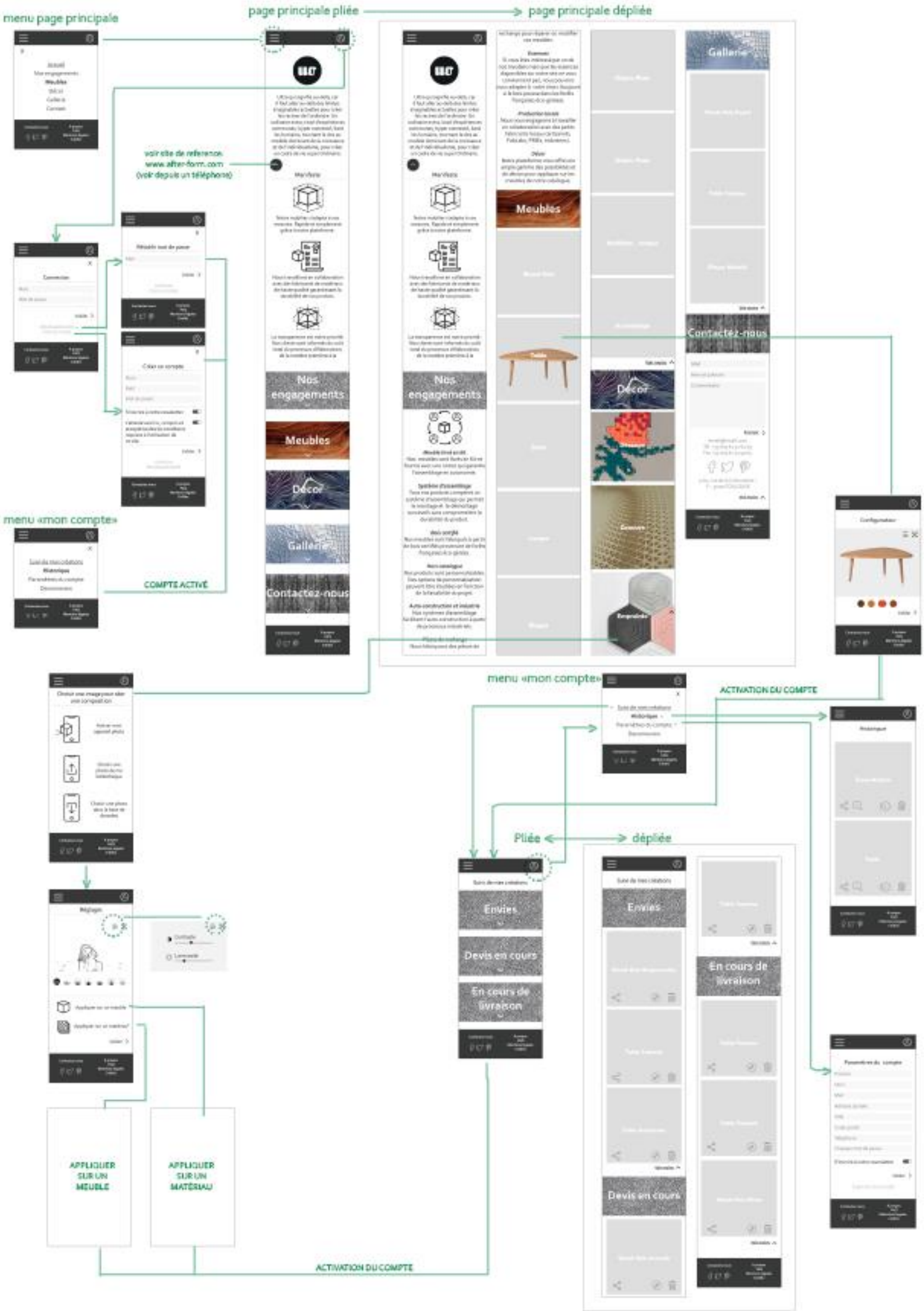
177
HEIGHT (CM)
70
Valider

A2. App specification front-end (ideas & client)




menu page principale
page principale pliée
page principale dépliée
voir site de reference
www.after-form.com
(voir depuis un téléphone)
Nos engagements
Meubles
Décor
Gallerie
Contactez-nous
menu «mon compte»
COMPTE ACTIVÉ
menu «mon compte»
ACTIVATION DU COMPTE
Pliée
dépliée
Envies
Devis en cours
En cours de livraison
APPLIQUER SUR UN MEUBLE
APPLIQUER SUR UN MATÉRIAU
ACTIVATION DU COMPTE

A3. Autonomous lamp state-of-the-art

A relevant and complete document, realized during the lamp project, and in French language, is attached to this report [***Autonomous_Lamp_State_Of_The_Art.pdf***] and refers all the research work done in this domain.