Talos

An Arduino fingerprint based smart lock

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1 Introduction

Talos is an Arduino-based device designed to control a switch(in our case a lock) in simple and intuitive ways, ranging from a fingerprint reader, to an rfid card, to an android app.
It's usage is rooted in intuitivity, where most of the work was designing an effective interface both physically(the lock device) and digitally(the android based app).

The final user has the role of the master, administrating through the app the full control of the physical device, where it can control both the status of the lock(Open/closed) and the permission of entrance, with the possibility of adding a profile for each subject he wants to add permissions of entrance to the lock-delimited room or space.
The master can also remove the permission of a certain subject, or even of all the added subjects(excluded itself); or, it could do the exact opposite, granting permission of entrance to all the registered subjects.

Moreover, an user can also control the lock both via a dedicated button in the app and with a special rfid card - a sort of passepartout.

Now to the structure of this short paper; introduction aside, this report is divided into 4 section, the first introducing the work in more detail;in the second we introduce the personas and the needfinding process behind the idea; the third section will illustrate the usability testing and their results, and a final section where we'll discuss the conclusions and possible future expansions of the project.

2 Technical overview and methodologies

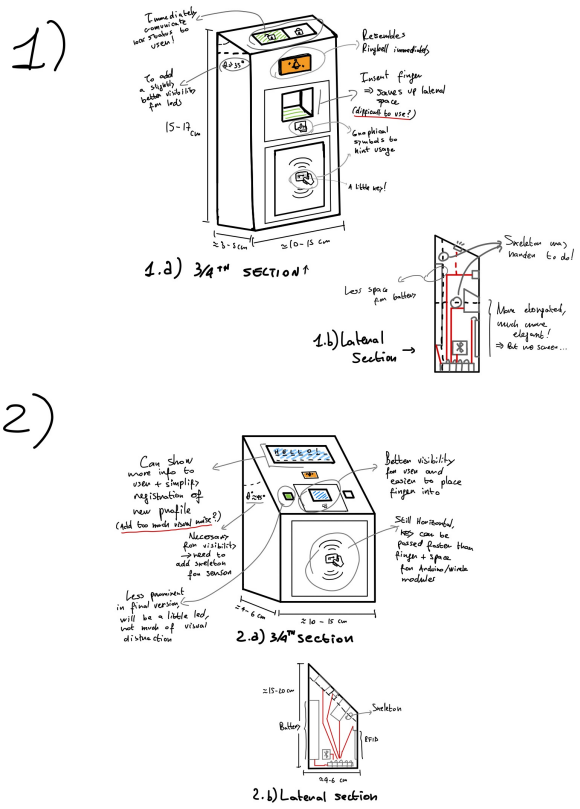
The project is divided into 2 main parts, an arduino device (and subsequently its code) and an android app.

2.1 Arduino device

To develop the first part, I used the Arduino IDE for the code and the following components:

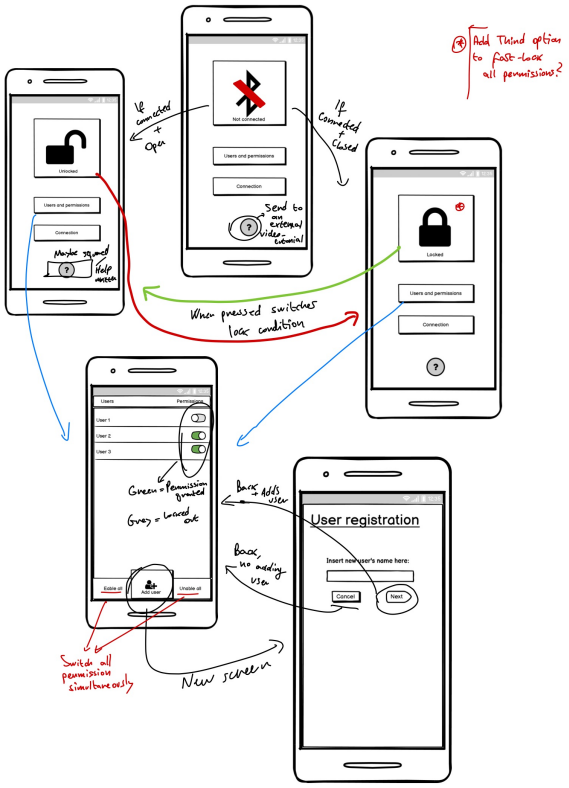
- **Arduino Uno**: the core of the physical part of the device, a smaller version may work as well but the Uno provided more flexibility and power to support all the components;
- **Fingerprint sensor**: a simple fingerprint optical scanner that can register up to 250 fingerprints unique id's;
- **Bluetooth HC-05 module**: a bluetooth slave only module, that once paired fr the first time can automatically reconnect with the paired device. It can be used to both send signals to the android app using it as an arduino serial output;
- **Button**: a simple button used as a doorbell, to request access to the master;
- **Leds**: 2 colored leds(red and green) to indicate the status of the lock to a bystander;
- **Led monitor**: a led dynamically programmable monitor with up to 32 characters writable at the same time, used to communicate with the user even when the smartphone device is not bluetooth paired;
- **Buzzer**: a simple siren to work as a bell.

Since the components are numerous enough, the device design should have been able to contain all this pieces without looking messy or confusionary: here a first interaction with the test user was crucial, and helped shrinking the possible solutions and improve the ones already hypotesized.
Here, the device's first drafts and the user testing preferences that led to the final version(shown in the next paragraph):



2.2 Android app

Then, the application: since the graphical aspect was the most important to provide a clean, easy to use(and learn) interface, I opted for a peculiar but effective IDE, the MIT appInventor,a free component based langauge.
Following, the mockups used as a reference.



Another preliminary user testing was done here, asking for preferences between the versions seen before.
Once again, we'll see the final implemented result later in this paper.

3 Needfinding

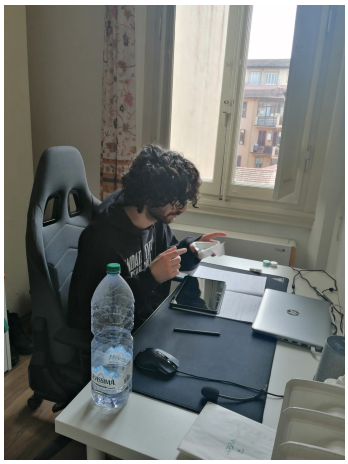
Needfinding was quite easy, since the creation of such a device was almost necessary for mine and my roommates everyday life; to better explain the needs we'll now introduce our personas.

3.1 Personas

Here our primary personas:

- **Francesco**: Francesco is a 23 years old college student, studying math.
  He loves videogames, and spends much of his day in his room, comfy in his gaming chair.
  As every mathematician he's as precise with his notes as messy with his room, often finding himself covered in papers and old t-shirts.
  When he's in his gaming(or, more rarely, study) sessions, he likes to concentrate on them, isolating a little from his noisy room-

mates.



- **Emanuele**: Med student, Emanuele is a 23 years old young but very mature guy, that already set his priorities straight and with a great sense of duty.
  He has a girlfriend with whom he shares most of his daily routine, and loves to reserves himself and with his fiancé moments of intimacy and privacy.
  He also likes to spend time with his roommates, especially on lunch and dinner, as a big family.
  Great fan of Calisthenics, he rarely skips a day of training; overall, he's a very methodical guy that likes full control in his everyday life.

We now proceed to introduce the secondary personas(in our case, only one particular secondary persona):

- **Roberto**: Roberto is a middle aged man, that weirdly looks way younger than his true age.
  Probably also because of this, he's still very active and likes to constantly keep himself busy with new ideas, both in his work and in his free time.
  He's an old school computer programmer, and while he understands technology way better than his peers, he still has some difficulties approaching with smartphones and such.
  Very practical guy, thanks to working for almost 40 years in the industrial environment, knows all the secrets and needs of such a field.

Let's now move on and see some possible scenarios;

3.2 Scenarios

- Francesco has an important test session in 5 days, and needs to study as hard as he can to pass it.
  Unluckily, his roommates often need to enter in his room to take a shared battery charger. Since he likes to lock his room, he would like to have a way to **open to his roommates without having to walk all the way to the door** locker; Unfortunately, his room has only an old, weak lock, that requires him to walk every time from the desk to the door to open, without any key to lend to his rommates.

- A new delimited sector has been built in Roberto's workplace, and him being the IT admin has now to find a way to control who can access to the new sector, checking remothely status of the door delimiting the zone.

He would like to have a way to **secure the zone and checking the situation at the same time**, maybe with a **physical access key** so that the colleagues can automously pass it to each other at the shift time.

- With the summer behind the corner, Emanuele wants to greatly increase his effort on physical fitness, and to do so has decided to buy a new set of high quality, very costly weights.
  On the other hands, he also knows that for the good season he will need to return to his actual home every weekend or so to help his familiy's restaurant - and his room has no key or locker of sort.
  He needs **a way to secure his room when he's away**, without the possibility for someone to enter the room without his permission.

- Francesco has finally took all his exams at uni, and now has some free time to spend on his favourite hobby, videogaming; since he likes to immerse himself in the activity, he bought a new pair of powerful headphones.
  So powerful, that often he can't hear his roommates banging on his door to ask to open.
  Francesco (and maybe his roommate even more) would like to have a way **to be notified when someone wants to enter his room**, with **more that only a sound warning**.

3.3 Requirements

We can definitively see what clear necessities are emerging through the scenarios examined before; from these, we can extract the following system requirements:

- **A way to remotely control the door lock**: From the scenarios a clear necessity seems to being able to pilot the door lock even when relatively far from it, without having to move from ones station.
- **A clear indicator to visualize the lock status**: To have an intuitive indicator of the status of the door, both outside and inside the room, and even at distance.
- **Create a device applicable with ease outside every kind of door**: An important feature seems to be to create a device such that its application should be separated from the physical connotations of the door, or in other words, a device that don't necessarily replace the whole lock.
- **Notify the request of an external user to have access to the room**: A basic necessity for a door, but that seems to be particularly important for the personas interviewed - a sort of smart doorbell, so to speak.

These requirements are the foundations of the work here discussed, and justify the designs and mockups previously presented in more than a way; starting from what we have seen and designed, we'll now see how and if the implementation mixed the things up.

4 Implementation

4.1 Physical Device

For the physical device implementation, after a quick survey to 5 people circa, the chosen design leaned to the second one seen in figure 1; this choice was also strengthened by usability and technical reasons.
First of all, a slightly wider but less deeper device may fit better in the scenarios hypothesised before, better integrating into the environment - usually, common light switches situated near doors are horizontally-shaped, so such a design would be less out of tune with the device ideal placement.
Moreover, the adding of a led screen may increase users navigation and app implementation; in fact, it's used both to signal status and relative changes due to user's actions and to guide the latter in the registration of a new fingerprint profile (way more intuitive than following the instruction on the app and having to place the finger on the physical device).

Here we can see the final version of the device prototype:

Here we see an example of the led screen instructions showed to the user in the new fingerprint registration phase, with the device notifying the unlocked status:

4.2 Android App

Since the MIT App Inventor environment provides special attention to the visual side of an application, the design seen in the mock-ups section was barely changed, with the final version of the app presenting itself as designed.
Following here we can see the screenshots of the main page, in the 3 possible status:

The help button sends the user to a quick video tutorial posted on youtube, that explains to the user all of its possible actions and the meaning of each button. If the device is yet to connect to the physical device via bluetooth, pressing the connect button (or the central control button) will show a list of all the possible devices to connect to; after the first time, an user should not need to perform this passage anymore, since the app automatically connects to the physical device if it's possible.

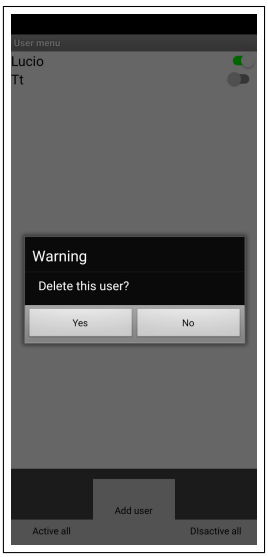
Once the device is connected an user can also manage the entrance permissions or add/remove a profile.
Here it is how the registration phase looks in the app.
First, once the user tap the "Add user" button, an input window opens up to let the user digit the new profile's name(or id):

At this point, the app enters in waiting mode,

advising the user to follow the instruction on the physical device's screen in order to complete the registration; in case of failure, the app simply notify the user of the error while the device's screen explain the motivation of the fail:

Once the device has registered the new profile, a message to notify the user of the success is shown and the new profile is added to the control list:

Once a new profile is successfully registered, the user can now manage it with the possibility to allow or disallow its unlocking permissions, or even removing it permanently, with a long press on the chosen profile row:



5 Usability Test

In the creation of both device and app, a great usage of interview was done.
In fact, 3 different interview were done, in different stages of the process:

1. **Designing stage**: In the first test, a simple choice was presented to a very strict number of people(3), to choose between the 2 possible design for the physical design.
   In this case, the choice fell on 67% of the case on the design marked as "1" in the figure 1; interestingly enough, a successive test run on the same group - now presented with the cardboard version of the 2 designs - inverted the previous result, with preference now shifting in 100% of the cases in the design marked as "2".
   When asked why, the group responded that, while the first design **looked** better, in the cardboard implementation it resulted way more uncomfortable, especially for the finger placement.
   This lead to the choice of the second design for the successive development.

2. **Raw prototype stage**: In this stage, where the device was working but not assembled with the actual case, but only with a cardboard version of it, a quick test on the same group as before was run in order to investigate the sensation and raw feedback given by

the device.
Suggestion were a faster unlocking time and an additional feedback to reinforce the unlocking action.
The last suggestion led to the addition of the buzzer module, in order to strengthen the sensation of positive action.
Also, a preview version of the app was shown to ask about appearance, with the prevalent suggestion to change the background to make the experience more pleasure - with the background initially pure white.

3. **Final usability test**: With the "complete" version of both the device and app, i then finally proceeded to a more structured test.This time the pool of people was larger, 5 in total, and different from the group used before for the 2 previous tests.The test consisted in a series of 5 tasks, each one in a different scenario presented by the supervisor.
The environment were the tests were done was in the supervisor's lab, where a little replica of a door with a lock was placed. The supervisor could also give some tips to the user if it appeared stucked. The tasks were the following:

   - Open the app and connect to the device;
   - Unlock and then lock the door;
   - Register a new fingerprint profile;
   - Give entrance permission to the new profile;
   - Delete permanently the newly created profile;

   After the completion of the test, the subject were requested to compile a SEQ test, here visible with the resuls:

N	Question	Mean Rating	σ
1	The app design is intuitive and pleasant	5.6	1.51
2	The meaning of the app buttons is clear	6.6	0.89
3	The feedback to inputs from the app is fast and responsive	5.8	1.09
4	Connecting to the physical device is difficult and counterintuitive	1.8	0.83
5	It was clear whether a user registration was successful or not	7	0
6	Adding a user is difficult	1	0
7	Removing a user is easy	5.8	0.83
8	The status of the lock is well indicated by the app	7	0
9	The meaning of the notifications is clear	6.4	0.54
10	The management of user permissions is intuitive	6.8	0.44
11	The opening speed of the lock from the physical device is acceptable	6.4	0.89
12	The use of the physical device is intuitive	6.4	0.89
13	The physical device design and appearance is pleasant	5.4	0.89
14	The status of the lock is well indicated by the physical device	7	0
15	The meaning of the indicators in the physical device is clear	6.6	0.54
16	Overall, the use of Talos is pleasant	6.4	0.89

As we can see, the app seems to be intuitive and pleasant enough, but overall lacks in appearance and particularly critical is the action of deletion of an user.
Also, after asking how to improve the usability of the app , 80% of the subjects suggested to present a brief tutorial screen when first opening the app, not only presenting it when the help button is pressed.
Also interestingly enough, none of the subject made use of the help button, suggesting that the button may need to be better highlighted or moved to another place in the screen, maybe more familiar with the help button placement pattern present in other app or digital environment.

6 Conclusion and future

The results found in the usability test lay the foundations for an extensive improvement, especially in the visual pleasure field.
Also, presenting an initial tutorial seems to be a crucial need not so much for users to absolve the tasks, which where completed by the whole group with minimal help, but to boost the initial intuitiveness, and as such giving back to the user since the very first moment a clear sensation of satisfaction in using the system.
Also, a possible addition to satisfy the needs even more may consist in adding a physical key for entrance; while possible, a great upgrade in technical components is needed to satisfy such a request.
Overall, we found that the system even in a prototypal stage seems to work absolving most if not all of the principal needs found through the initial observations.