École Polytechnique de Tunisie

Module: ingénierie du transport et de l'infrastructre

Smart bus

Project report

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1 Introduction

In the of the module « ingénierie de transport et de l'infrastructure » at Ecole Polytechnique de Tunisie, we are supposed to do a project within the theme of the transport and infrastructure. We thought about the transportation problems in Tunisia due to its importance in driving the economy in all countries in the world. The buses infrastructure in Tunisia is suffering from many problems and we tried to find a solution that can help make the situation better for both the transportation companies and the customers alike.

2 The problems

The transport companies, more specifically the bus companies, have several problems and face different challenges throughout the year. Here are a few:

2.1 Unreliability

The bus often comes in unpredictable times. People are no longer surprised if the 8:30 bus arrives at the station at 9:00 or even later. So many people prefer taking a taxi not to be late for their jobs/studies.

2.2 Overcrowdedness

The buses are often overcrowded. The problem is that, at a given time, some lines are almost empty, and others are too crowded. A better lines management is definitely possible.

2.3 Fare evasion

The number of tickets sold is far off the number of real passengers on the bus.
These challenges concern both public and private companies, even though public companies seem to suffer the most.

3 Our solution

Our project is an attempt to solve the problems mentioned above in order to enhance the performance of the transport company and to make costumers happy. It is a technological solution that consists in the following:

- A connected IoT system mounted on the bus and that collects valuable data such as the real time position and the number of passengers getting on and off the bus in each station.

- Artificial intelligence algorithms that can make use of the collected data in order to make useful predictions such as the exact expected bus arrival time and the expected number of passengers.
- A mobile application that can aggregate this information and present it to the user in a pleasant and appealing form: the bus station position, the estimated time of arrival of the bus, the level of comfort …
- A monitoring system that can give a lot more visibility to the company: the real number of passengers, the lines in which there are the most fraud…

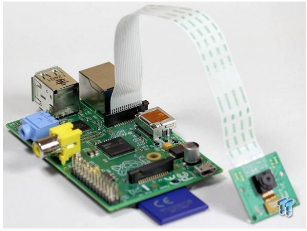
4 The benefits for the company

Our solution is an opportunity for the transport company to be more competitive, to increase customer satisfaction (and therefore to gain market share) and to enter the data driven decisions era. In fact: More and more customers will make the switch from taxis to the smart buses thanks to the increased reliability of the service, the enhanced comfort levels, and to the futuristic mobile app that can indirectly prove that the company does care about its customers. The data collected can be very valuable to the company, too. Aside from the predictions that can be made using this data, it can be aggregated in a dashboard that can give more visibility on how the company is behaving and how to optimize its performance.
Concerning the fare evasion, the company can compare the number of sold tickets to the real number of passengers that took the bus in each line. That way, it can know where frauds are the most committed. It can then target particular lines to send inspectors to and therefore minimize the fare evasion.

5 The technical aspects of the project

5.1 The hardware

- A raspberry pi 3 card + GPS, Camera and cellular connectivity modules for each bus ($100)
- A server for data processing ($1000)

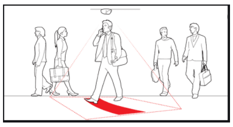


5.2 The software

- Passengers counting algorithm
- Bus arrival time prediction algorithms
- Passengers count prediction algorithm
- Data transfer protocol: Socket
- A mobile app (prototype)

5.3 How does it work?

The raspberry pi 3 is a cheap $35 computer to which many modules can be added.
In this project, we will use it along with the needed modules supposedly after mounting it over the door of the bus in the appropriate angle so that the camera can spot the people when they are moving near the door.



At each bus stop, the camera module starts sending the video stream to the raspberry pi. This video stream is then analyzed in real time using the modified OpenCV algorithm that runs on the raspberry pi card in order to extract the number of passengers that got on and off the bus in the station.

Regarding the potential privacy concerns, the video is never stored neither on the raspberry card nor in the server. The footage is destroyed from the ram memory as soon as the desired information are extracted.

As soon as the bus's door is closed and the bus is moving, these numbers, along with the GPS position that indicates in which bus station the information was collected, are ready to be sent to the server over an internet Socket. The server adds in this new row of information to the already existing database.

Once the data collection is over for the day, a machine learning algorithm is run on the server overnight.
This algorithm's idea is simple: based on the historical data and thus the experience it has learnt over a reasonable period of time, it gives two outputs:

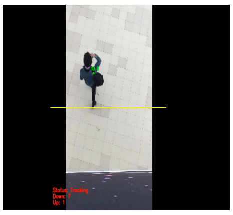
1. The predicted time of arrival of each bus on each. station
2. The number of passengers expected in each line.

This information is then made available for the mobile app whenever it makes a request for the server. The mobile app works as follows: the user chooses a destination, and based on the GPS position of the mobile phone, the app gives you the closest bus station and the estimated time of arrival of the bus as well as how comfortable the ride will be (based on the estimated number of passengers). The mobile app has a "driver" section that is only available for bus drivers. It allows the bus drivers to report problems such as a bus failure, road accidents etc.

6 Proofs of concept

We tried to implement a decent part of this big project. We managed to develop the following parts:

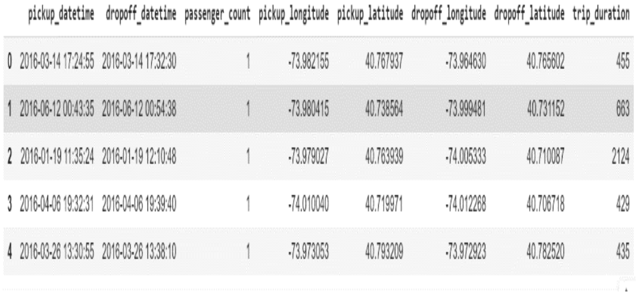
6.1 The passengers count algorithm



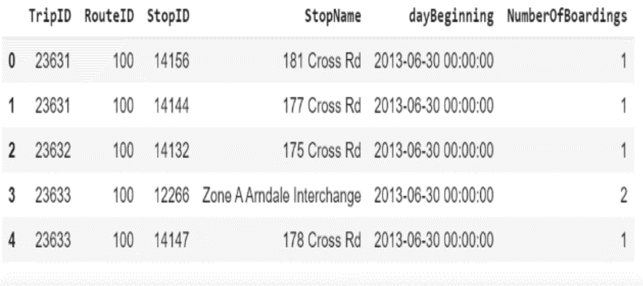
We used an open source algorithm based on OpenCV and Keras. We adapted the algorithm to our needs in order to work with the video stream coming from the camera module to the raspberry pi 3. We obviously did not have a bus to try it on, but we managed to prove that it is working by trying it on a video of our friends recorded in SupCom. The video will be provided in an attached file. The source code is in the attachements as well.

6.2 The two machine learning algorithms

We obviously don't have the real database required for the algorithms yet. So, we tried to look on the internet for databases to work on. Unfortunately, since the idea of the prediction algorithms might be unique of its kind, we didn't find a good database that has the 2 features in same time: the number of passengers along with the time of arrival of the buses. So, we worked on two separate algorithms: the first predicts the time of arrival in each station, and the second predicts the number of passengers between each two consecutive stations (Time series problems).

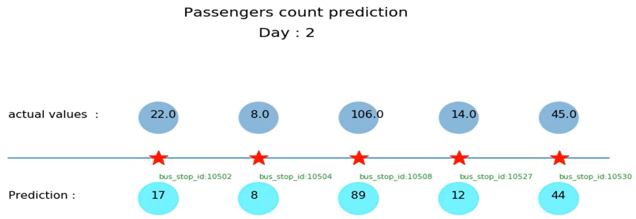


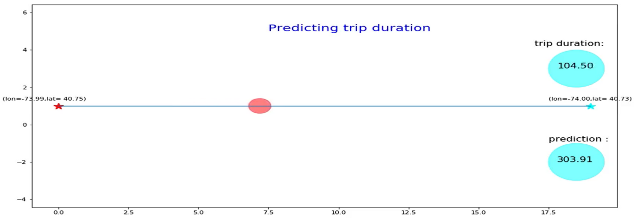
	pickup_datetime	dropoff_datetime	passenger_count	pickup_longitude	pickup_latitude	dropoff_longitude	dropoff_latitude	trip_duration
0	2016-03-14 17:24:55	2016-03-14 17:32:30	1	-73.982155	40.767937	-73.964630	40.765602	455
1	2016-06-12 00:43:35	2016-06-12 00:54:38	1	-73.980415	40.738564	-73.999481	40.731152	663
2	2016-01-19 11:35:24	2016-01-19 12:10:48	1	-73.979027	40.763939	-74.005333	40.710087	2124
3	2016-04-06 19:32:31	2016-04-06 19:39:40	1	-74.010040	40.719971	-74.012268	40.706718	429
4	2016-03-26 13:30:55	2016-03-26 13:38:10	1	-73.973053	40.793209	-73.972923	40.782520	435



	TripID	RouteID	StopID	StopName	dayBeginning	NumberOfBoardings
0	23631	100	14156	181 Cross Rd	2013-06-30 00:00:00	1
1	23631	100	14144	177 Cross Rd	2013-06-30 00:00:00	1
2	23632	100	14132	175 Cross Rd	2013-06-30 00:00:00	1
3	23633	100	12266	Zone A Arndale Interchange	2013-06-30 00:00:00	2
4	23633	100	14147	178 Cross Rd	2013-06-30 00:00:00	1

Finally, using these two algorithms, we have made a little video demonstration that is also attached to the report and these are two screenshots from the video simulation:.

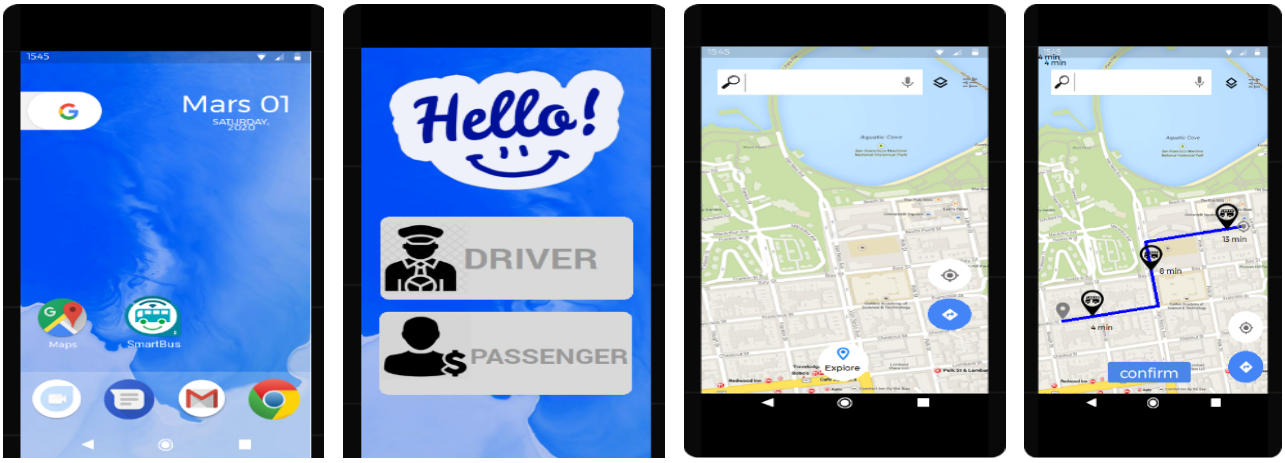




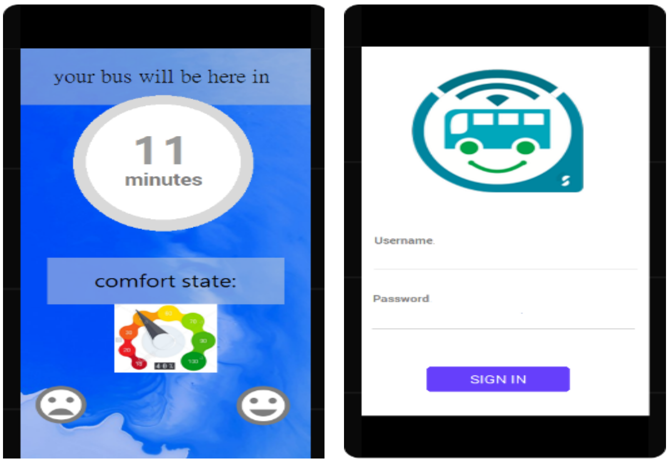
Once we have collected enough data for the company, the same algorithms can work with minimal modifications.

6.3 The mobile app prototype

We have also tried to make a mobile phone prototype in the form of screenshots of what the mobile app should look like:
When opening the app for the first time, you are asked if you would like a driver mode or a passenger mode. In the driver mode, you can find a map with a search box to indicate the desired destination.
The app then chooses the least crowded bus for you and gives you the position of the bus station as well as some useful information such as the estimated time of arrival and the comfort level on the bus.



In the driver mode, the bus driver would need to enter his secret ID and password and from there on there are shortcuts that he can use to report problems.



6.4 The data collection system

The data collected in each station needs to be sent to the server after each bus stop. To do this, we use a python program that sends the data on a secure socket over the internet. The connectivity of the raspberry card is assured thanks to the cellular data module.

Once the data is sent to the server, it is automatically added to the existing database on the server. The code for this program is also provided in the attached files.

7 Limitations & Perspectives

7.1 Limitations

In our project, we tried to implement the idea using the available hardware. However, there are some limitations such as:

- **Low light situations:** The camera might have a hard time detecting the moving passengers at night.

This may be solved using an infrared camera instead of a regular one for example.

- **Connectivity in rural areas:** The bus lines that pass by the suburbs might suffer from slow internet connection, especially between cities.

This can be solved by sending an additional data feature: the time of the data sample. That way, even if the sample was sent several minutes after it was captured, there would be no problem.

7.2 Perspectives

The work we have done is far from perfect. It can definitely be further developed, and we already have some ideas:

- **A bus allocation algorithm**

The information we can collect using the IoT system can be used to better allocate buses: in a given time, we can send more buses to the lines that are overcrowded and less buses to the lesser crowded lines.

- **Better prediction algorithms**

The prediction system might be enhanced further to become more precise when collecting additional data such as the weather, the driver ID, the bus brand…

8 Conclusion

This project is a solution that can make bus users' lives easier and has the potential make so much money for the bus companies and be ahead of the competition.
It was also an opportunity for us to work together on a small real-life project in an attempt to solve everyday problems using the new technologies such as the artificial intelligence algorithms and the Internet of Things solutions.
We hope that our project was decently thorough and maybe one day it will be actually implemented.