Final Degree Project

Bachelor's Degree in Industrial Electronics and Automatics Engineering

Smart roundabout

REPORT

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RESUM

Cada dia per anar de casa al treball haig de circular de mitjana per 11 rotondes, em permet sentir el tediós que resulta haver d'aturar-se de forma brusca és degut a la poca visibilitat d'aquestes i la imprevisibilitat de les traçades d'alguns conductors.

Això provoca que a més de fer un consum superior innecessari de frens també ho fem de combustible per introduir-nos a la rotonda, en alguns casos accelerant amb la mateixa innecessària violència. Tots dos casos generen la majoria de partícules contaminants a l'aire de les ciutats. També pretén evitar els accidents derivats d'aquests actes.

El meu objectiu tracta d'evitar aquestes situacions, sent les mesures aplicables de forma immediata, senzilla i econòmica.

La rotonda intel·ligent té un grup de sensors electromagnètics capaços de detectar velocitat i dimensions, a més porta instal·lats senyals de velocitat lluminoses programables que indicaran la velocitat que els vehicles hauran de circular per fer una entrada a la rotonda de la forma més eficient possible.

Els coneixements que he adquirit durant el grau em permet fer ús del software LabVIEW per a programar el control i un simulador que sigui capaç de mostrar el funcionament.

El control ha sigut satisfactori amb una freqüència de 2160 vehicles per hora, aquesta freqüència és considerada baixa. La simulació i el control aplicat té un error de ± 2,23 metres, aquest error en un control real pot ser eliminat, considerant que un humà és capaç de rectificar aquesta variació considero que és assumible.

Paraules clau (màxim 10):

Rotonda	Intel·ligent	Control	Programació
Conductors	Vehicles	Sensors	LabVIEW
Simulador	Contaminació		

ABSTRACT

Every single day to go from home to work, I have to drive on average through 11 roundabouts. It allows me to feel how much cumbersome is to stop brusquely because of the low visibility or the unpredictability of the traces of “some drivers”.

In addition to unnecessary braking, we also use too much fuel to speed up enough to go inside, in some cases with the same unnecessary violence. Both cases generate the majority of environmental pollution in cities. It also aims to avoid accidents arising from these acts.

My objective is to avoid these situations, being the measures applicable immediately, simply and economically.

Smart roundabout has a group of electromagnetic loops sensors capable of detecting speed and size installed about 30 meters away. Also, has installed programmable luminous speed signals that indicate the speed that the vehicles will have to circulate with to make the entrance as efficient as possible.

The knowledge I have acquired during the degree allows me to choose the LabVIEW software to program the control and a simulator capable of showing the behaviour.

The control has been satisfactory with a vehicle frequency of 2160 per hour, it’s considered low. The simulation and the applied control has an error of ± 2,23 meters, this can be eliminated in a real control, considering that a person is able to rectify this variation I consider that it is acceptable.

Keywords (10 maximum):

Roundabout	Smart	Control	Program
Drivers	Vehicles	Sensors	LabVIEW
Simulator	Pollution		

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1. GLOSSARY

A.C.: Altern Current

AP-7: Motorway

D.C.: Direct Current

DDM: Double Detector with Microprocessor

DGT 3.0: (Dirección General de Tráfico) Consists in a cloud to connect all vehicles to prevent accidents.

E-90: European route

LED: Light-Emitting Diode

PC: Personal Computer

PLC: Programmable logic controller

U.S. : United States

USA: United States of America

MDOT: Michigan Department of Transportation

2. INTRODUCTION

2.1. MOTIVATION

The main motivation has been the challenge of innovating in something that had born a century ago. I really want to change that kind of road constructions, to apply Industry 4.0 [1], to use interaction between infrastructure and people to increase safety on our roads.

Before choosing the project I was searching for internet about some related topics and I saw that interior ministry published a public contract which consists in creating a platform for DGT 3.0, and then I realized that all I want to apply to improve safety is sooner than I thought.

Finally, I chose Smart Roundabout as a project because the safety is what I want to devote to.

2.2. METHODOLOGY

I have structured the project in six phases:

Brainstorming, research, physical data collection, the creation of the simulator, creation of the control and analysis of the functioning.

2.3. PHASES DESCRIPTION

I started by thinking a good solution for the problems I found driving through roundabouts, after I was searching for the technology and companies which use them, I met with one of the engineers of Etra Bonal in his office. Once I knew how they solve their projects I began searching for a real example near my home, I drove through a roundabout few times to know most common speeds driving through.

After that, I started to program the simulator at the same time I was designing simulator interface.

Finally, I developed the control and tested her capabilities.

2.4. OBJECTIVES OF THE PROJECT

Amongst all the objectives, this project consists in to demonstrate that another kind of active safety could be applied on our roads just using current technology.

The main target is to create a satisfying control of vehicles applying Industry4.0, and prove that we are spending too much energy and making pollution with no sense.

Now, I know the mobility is a very important issue because of overcrowding of vehicles. These cause traffic problems, noise and pollution. Then, I want to take action on this matter and demonstrate that we could decrease all of these problems.

Therefore, I have divided the principal big objective into small ones.

To think about which solution could be applied, this consists in think about current technology, I want to apply existing technology to create something that can be used as soon as possible, cultural arrangement, everybody has to be ready to interact with this technology without problems, easily applicable, for the first reason and economics reasons we can't expend tons of money on it, the solution has to be economic and as simple as possible.

At this time, I need a platform to construct the solution, this one should be known by me at least a little and I can choose among some software that I used during my degree, this software has to have code interface for the program the control and a user interface to show a simulation. Then the other objectives are to create the control and simulator.

The last objective is to get de capabilities of the control and the simulator, I need to confirm if the first design was enough to comply with the requirements.

In brief, the control must help drivers to go into the roundabout with the minimum of effort the control needs to calculate the best way and communicate to the drivers.

2.5. HYPOTHESIS

The control of the roundabout [2][3] with four entrances and one single lane using four sensors and four indicators, one for each entrance can avoid the total braking of the vehicles.

3. ROUNDABOUT

3.1. THE BIRTH

A roundabout, also called a traffic circle, road circle, rotary, rotunda or island, is a type of circular intersection or junction in which road traffic flows almost continuously in one direction around a central island.

Picture 1. **Roundabout of 4 entrances (MDOT)**

The first was built in 1976, the father of the invention was Eugène Hénard (1849-1923), a French architect who designed the first urban roundabouts in Paris. The first attempt to introduce this type of intersection in Spain dates back to 1974, 50 roundabouts were projected without success for the Metropolitan Arterial Network of Catalonia. The first Spanish roundabout was built in Palmanova (Mallorca) in 1976 [4].

3.2. INNOVATION IN ROUNDABOUTS

From 1976 to now, engineers were innovating on roundabouts, currently we can watch on our roads these kind of roundabouts.

Picture 2. **Turbo roundabout**

Turbo roundabout aims to avoid accidents by lateral impact, then it needs to make restrictions in the lateral movements between roads, in many of these limited by continuous line.

To put traffic lights inside of roundabouts sounds illogical, but the reason for introducing them is to dose the flow of vehicles with an external control.

Picture 3. **Plaza España (Barcelona)**

It is easy to saturate a roundabout of these dimensions if we do not apply the properly control of the entrances and exits. As you can see in the picture 4, with a totally saturation.

Picture 4. **Saturated roundabout**

I have observed that some traffic jams are caused by the imprecision of the drivers when entering and the way it is circulated. Of the first 20 web pages that we found when searching for the word "roundabout" in Google, 16 talks about how we have to circulate through, this is a symptom that is a notorious problem.

3.3. Innovation in control speed

I consider that now we are using three principle real innovations in control speed.

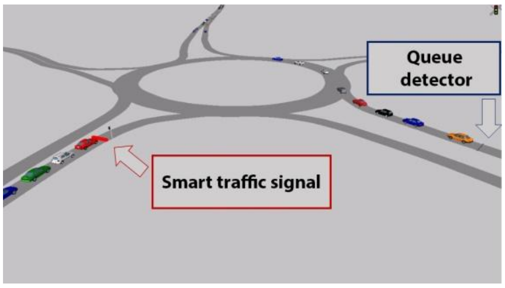
It is easy to see this kind of traffic lights; they are fixing the limit speed for each lane, this permit to regulate the speed independently.

Picture 5. **Main road C-32**

It is common to see lower speeds limits on saturated lanes. Especially to enter another main road like E-90 to AP-7 in Catalonia. This type of control aims to limit the speed to avoid accidents by rear reach. The speeds are controlled from the volume of vehicles that are present a kilometre ahead.

Picture 6. **Traffic signal in BV2041**

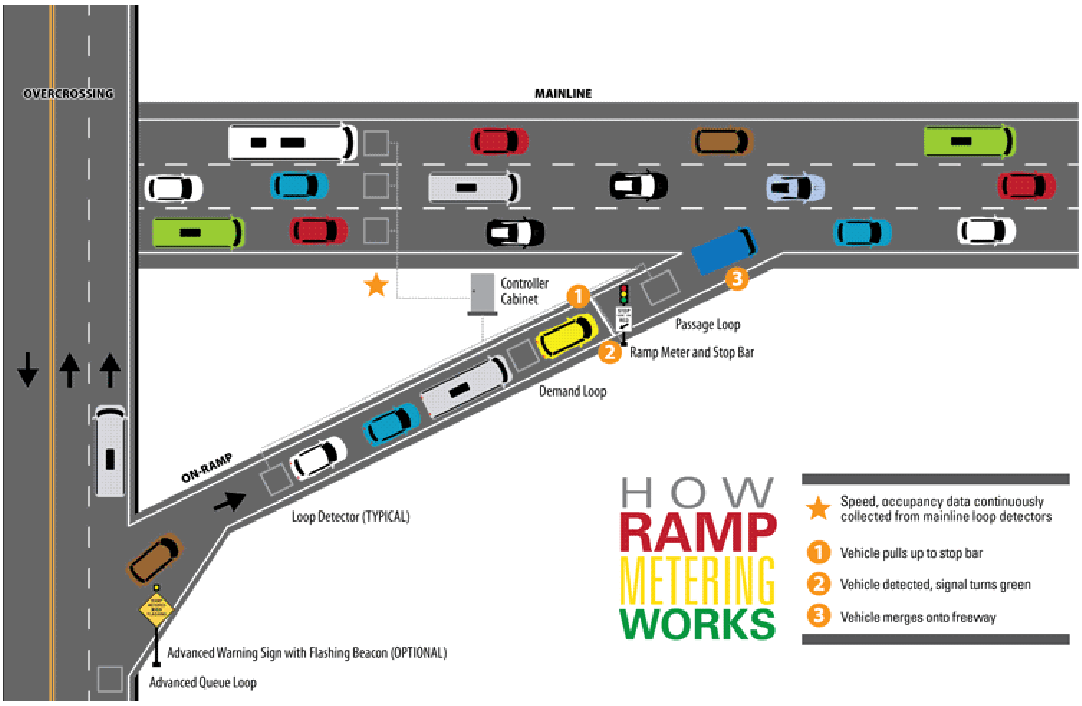
This traffic signal warns that if you drive over the speed limit that shows to you the next semaphore you will find will be on red. In this case, her purpose is became safer the entry and exit of vehicles with poor visibility. This limitation permit to make these manoeuvres easier. Before the installation, people spent too much time waiting for a good opportunity to access.



Picture 7. **Ramp meter on roundabout**

Picture 8. Traffic light with restriction below

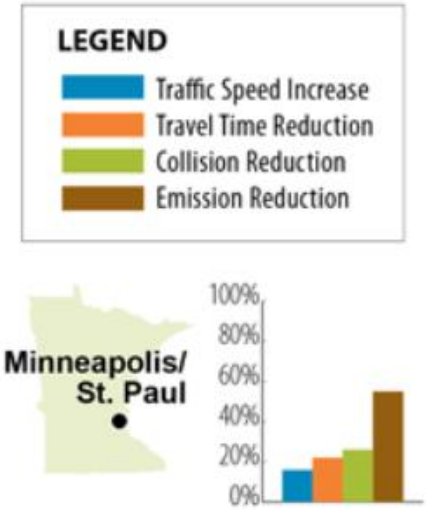
Finally, a control that we can't see now in Spain but is very common in USA (United States of America). Ramp Meter is a system that detects traffic jams and activate semaphores to dose the traffic of the other roads. We can arrive to this control, and look how for each green line only cross one or two cars with a frequency of 5 to 6 seconds. Picture 9 shows how ramp metering works.



Picture 9. Working sketch of ramp metering

U.S. Department of Transportation's website shows some interesting data about the benefits [5].

They insure that Minneapolis identified a net annual savings of 1.160 tons of emissions and reducing CO emissions by 1.195 tons per year. We can see an example on the same website.



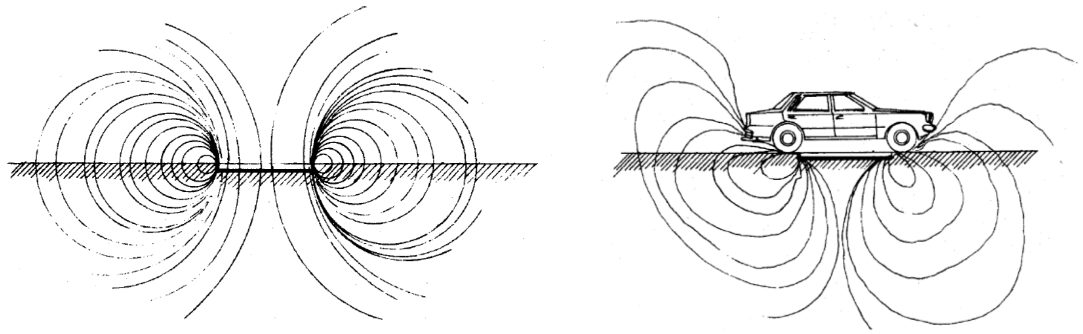
Graphic 1. Data of benefits in Minneapolis/St. Paul

This confirms that this kind of control can make our roads more efficient.

4. INDUCTION LOOP

Studying these solutions I noticed the way they use to acquire the data for control.

Her name is inductive loop [6], is an electromagnetic detection system which uses a moving magnet or an alternating current to induce an electric current in a nearby wire. When metallic pieces of the vehicles cross the influence zone provoke alterations, this means that the inductance (L) changes, therefore, a variation of frequency (W).



Picture 10. **Induction representation**

The operation of the oscillator is independent for each loops, there being no coupling between the frequencies of both loops, since the sampling is done in an alternative. The device has the peculiarity of allowing the programming of detection response sensitivity, the oscillator work with different frequencies, this avoid the coupling between the different detectors that are installed nearby, and the programming of different periods during the detector remains in response, in the presence of vehicles. The dominant parameters of the inductive loop detector are:

4.1. RESPONSE SENSITIVITY - DL / L (%)

It is defined as the minimum change produced in the inductance, and that causes the detector to respond. There are several types of response sensitivity: 0.02, 0.1, 0.2, 0.4 and 0.8 (dL / L (%)). The 0.2 is the normal value for automobile detection, 0.1 for mopeds and the 0.02 for bicycles. The inductive load can vary between 50 and 700 microhenries, remaining the frequency level of oscillator operation between 30 and 120 kHz.

4.2. INHIBITION TIME

Inhibition time is the period of time that the detector needs to get used to an invariable situation, this means that if a vehicle stays over the detector for more than the inhibition time, the detector will ignore the vehicle.

Once this time has passed, the detector adapts to the new situation and is available to new detections. Like responsive sensitivity, the time of inhibition has four possible time periods: 15 seconds, 1 minute, 3 minutes and 15 minutes.

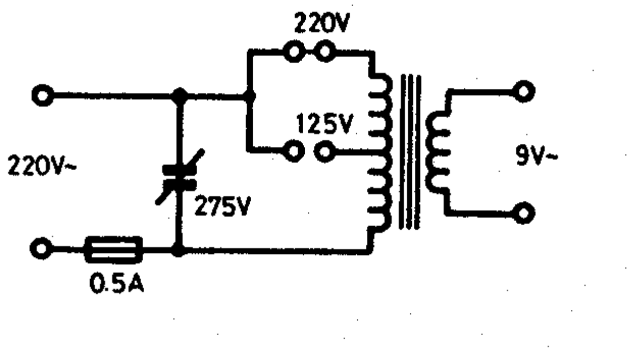
The detector allows choosing between three frequency values for a fixed value of inductance. This possibility is an additional guarantee to avoid couplings between next loops. The device presents the following security system:

- Over current protection:

In the case of the DDM detector with power supply built-in, is provided with a 0.5 fuse amps.

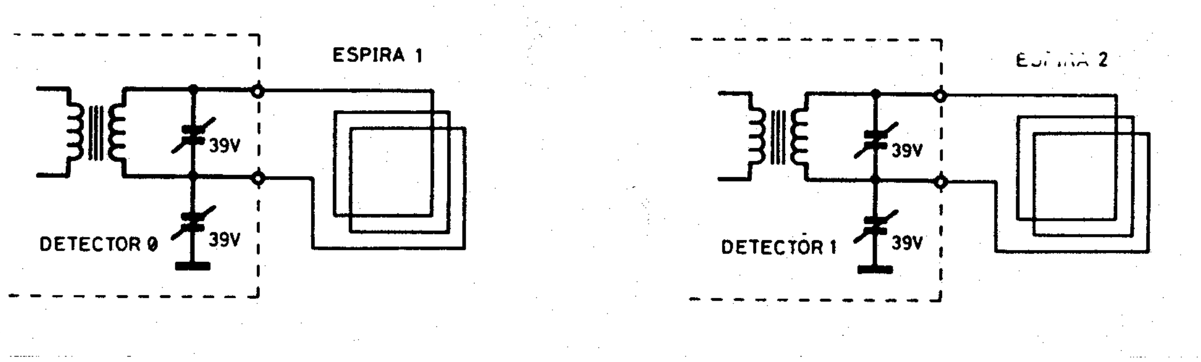
- Protection of overvoltage in the relay output:

In the electrodynamics option, it has 4 varistoes of 250 V to short-circuit possible surges. If the DDM has a power supply, it has a 275 V varistoes to the transformer input with the same purpose previously stated.



Picture 11. **Protection of DDM**

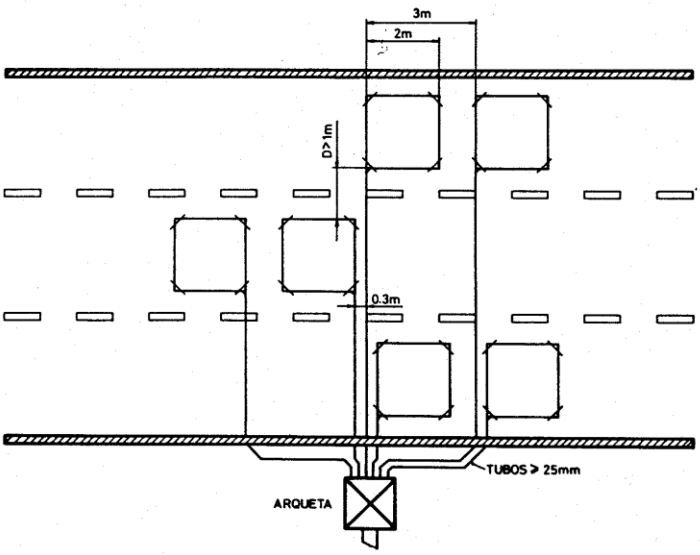
In any type of option, the device incorporates four more varistoes, that short circuit overvoltage produced in the loops.



Picture 12. **Loops connection**

4.3. INSTALLATION

This is an example of layout on a four-lane road.



Picture 13. **Loops installation**

The distance between both loops can be less than 1 m, but they advise that between the different lanes there must be a distance of at least 1 m. The cable must be paired from the loop output to the detector, with a maximum recommended of 300 m. If you try to match manually, give 5 to 8 laps per meter. For more than 10 m of separation, cable type 1,3 mm diameter should be installed.

In the following table we can find the number of loops to be made depending on the size of the area to be detected.

	NUMBER OF LOOPS					
	N° 2		N° 3		N° 4	
Lenght / Width	1,5	2,5	1,5	2,5	1,5	2,5
1 m	10	18	35	52	72	110
1,5 m	15	31	50	74	100	150
2 m	27	42	66	93	130	175
2,5 m	32	50	81	109	155	210
3 m	40	58	96	125	175	232
3,5 m	44	68	111	142	198	256
4 m	50	72	126	160	223	282
4,5 m	57	81	142	179	250	310
5 m	62	89	158	198	280	340

Table 1. **Induction of the turn according to the number of turns and their dimensions**

The placement of the sensor requires the realization of a cut in the asphalt of at least 25mm depth.

Picture 14. **Cutting a slot**

Once the cable is secured inside the slot, it is necessary to apply sealant or tar.

Picture 15. **Applying sealer**

Finally you have to connect the sensor to your DMM.

4.4. SPEED CONTROL

Two consecutive loops are used, finding the speed from the time the vehicle passes through each one of them and through the space between the loops. DDM is particularly useful in these cases; first, by its speed of operation, and second, because the separation between turns can be the one that the installer wishes to have, without couplings between them, the specifications are in the annex.

5. FIELDWORK

5.1. DATA COLLECTION

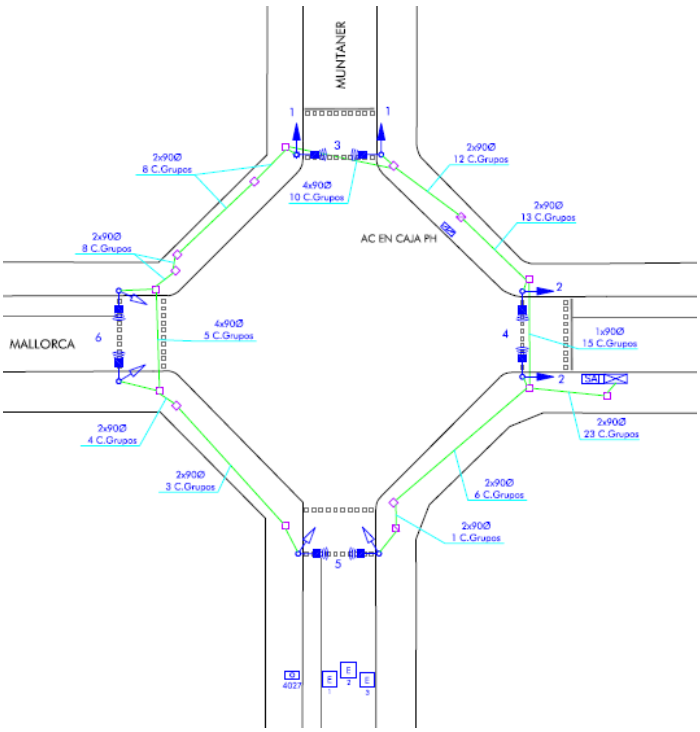
During the first part of the project I conducted an interview with the people responsible of the traffic lights in Barcelona, an engineer from the company Etra Bonal explained me how they install the signalling and control elements, as well as the maintenance they perform on them and the data they use.

He told me that in Barcelona the use of the loops sensors are only to know the passage of vehicles through them, it allows to recognize the movement of the masses of vehicles and being able to dose the flows correctly by increasing or reducing the times of the cycles of the traffic lights.

In addition, he explained me how they applied controls for established schedules, prioritizing some roads with respect to others due to the large volume of vehicles that circulate at specific hours, as the rush hours.

During the interview he showed me the plans about the works they were doing in Barcelona as well as time and budget dedicated. The construction can be extended for three weeks with four workers while the installation would be carried out in four days with the same number of workers.

The total cost of the project is approximately 40.000€, these data are for a crossing of the following characteristics.



Picture 16. **Crossing scheme**

- 8 traffic lights for vehicles.
- 8 traffic lights for pedestrians.
- 3 loops (boxes with an E).
- 1 SAI.

- Cables.

The second part of fieldwork is based on taking experimental data by driving through the roads of nearby towns. The type of roundabout that I tried to control is similar to the one that we can find in the outer roads of the population of Gavà, which lorry can't circulate by.

Diameter roundabout (m)	Total diameter (m)	Rail width (m)	Maximum external speed (km/h)	Interior maximum speed (km/h)	Number of ways	Number of entries	Number of departures
5,8	21,2	4,80	45	30	1	4	4

Table 2. **Roundabout features**

We choose these measures because they are larger dimension than Spanish regulation's request, which allows building lanes at least 3.5 meters of wide.

Limiting the number of roads to one allows us to have a greater precision in the control because the overtaking is restricted. In addition, initially, I wanted to install the sensors to the entrances to a certain distance, to specify later, and to the exits of the roundabouts. Finally, I decided to choose only one sensor per entrance, because the inaccuracies may lead to complications that would not have allowed me to finish the control.

5.2. Choice of software

Initially, as I show in the initial project proposal, I wanted to make a combination between PLC's and LabVIEW, due to the ignorance about the operation of the real architectures of the controls. The engineer of Etra Bonal explained to me that his architecture was like PC and fed by cards of data acquisition. This made me discard the PLC control.

I had in mind to use Visual Studio, or even software dedicated to the simulation, but they turned out to be more complicated and limited for my application. These were not focused on designing roundabouts, this is the case of AutoTURN and TORUS, who granted me student licenses free of charge and very kindly. Once tested, I confirmed that it would not be possible to obtain the result I wanted, because the code is mostly closed.

Finally, I opted for LabVIEW 2017, this software has a user interface, which allowed me to visualize the model I wanted and visual programming that is much easier to develop. During the degree, we programmed with LabVIEW analog data acquisition and creating simulations.

5.3. Concept

Before starting the simulator programming, I had to specify what I wanted to simulate, how I am going to acquire the data and how the control is going to be carried out. The idea is to indicate to the drivers how fast they should go for not to encounter any obstacle when entering the roundabout at a sufficient distance to make it possible. For this, it is necessary to know the dimensions and speeds of the vehicles that circulate through them and to make calculations explained in section 5.4.2., as well, to indicate correctly by light signals and with communication as we saw in picture 17, but with the difference that they won't be of maximum speed, they will be of advised speed as we can see in the following image, the speed once inside the roundabout would be fixed for all the vehicles.

Picture 17. **Recommendation signal**

In order not to cause confusion, it is necessary to paint on the ground the area where the vehicle will be located, where it will show them the recommended speed. Therefore, the necessary elements for this roundabout are:

• Acquisition of data at a distance from the entrance to a roundabout.

• Road markings for positioning.

• Illuminated signs.

• Electronic control and electrical connection.

5.4. SIMULATOR

The simulator had an enormous weight in the project, it had to be totally modular and compatible with the control that I will apply later.

5.4.1. INTERFACE

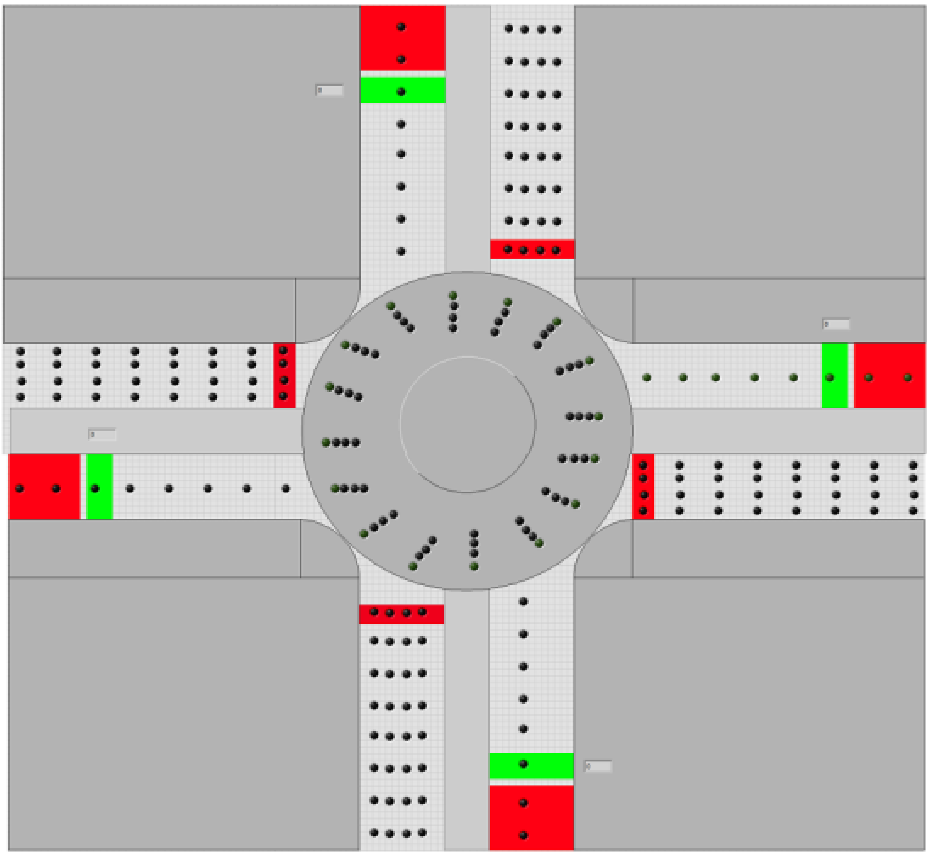
The user interface of the simulator had to be similar to the selected model, but at the same time be able to simulate another type of configuration [7][8][9]. The interface consists of a central rotary and four incoming lanes and four projections, in addition to a single lane ring that surrounds the roundabout.

The vehicles will be distinguished in three types, making reference to data of new registrations in December, 2017 in Spain, I extrapolated the type of circulation that we can see in our roads, therefore, classifying this data of vehicles such as motorcycles, buses and commercial vehicles and cars, I got that:

Type	Registrations 2017	%	LEDs
A (Cars)	301.797	61,63	3-4
B (Motorcycles)	159.372	32,54	1-2
C (Buses)	28.482	5,81	6-7

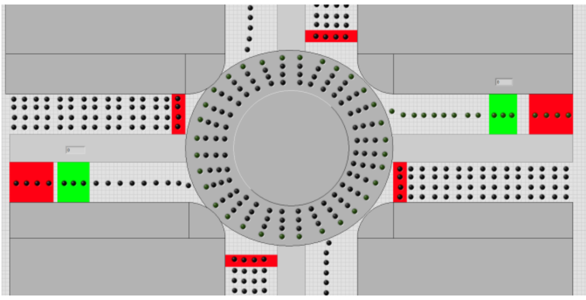
Table 3. **Information about registrations of vehicles Dec. 2017**

This data allowed me to generate a realistic circulation and be represented in the simulation by LEDs in the front panel. Continuous LEDs indicate the length of these vehicles, and their movement indicates the speed they have and the circulation they perform. The colors determine the entrance from which they come. The interface is full of LEDs to show whereby the vehicles are moving, in order to be analyzed the LEDs were displayed unfolded, looking if each vehicle circulates differently, this allows seeing in which places both vehicles would coincide. In the new versions, these LEDs are invisible until they are activated to capture attention only on the important elements.
The first version is the one [10] that we can see in the following figure, red box is the zone where the sensors are installed and the green box where is shown the speed they should circulate.



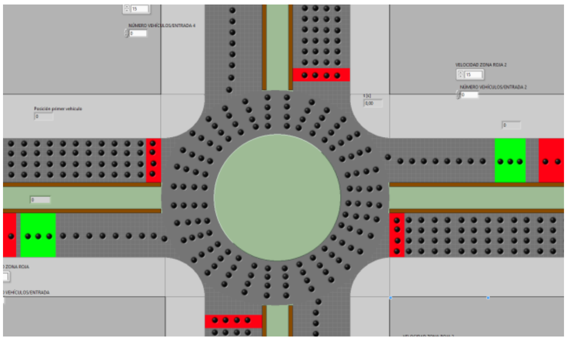
Picture 18. **First version of interface**

The second improvement was made because it had a very low resolution, leaving too many gaps and I did not see what happened if there were impacts or just did not touch.



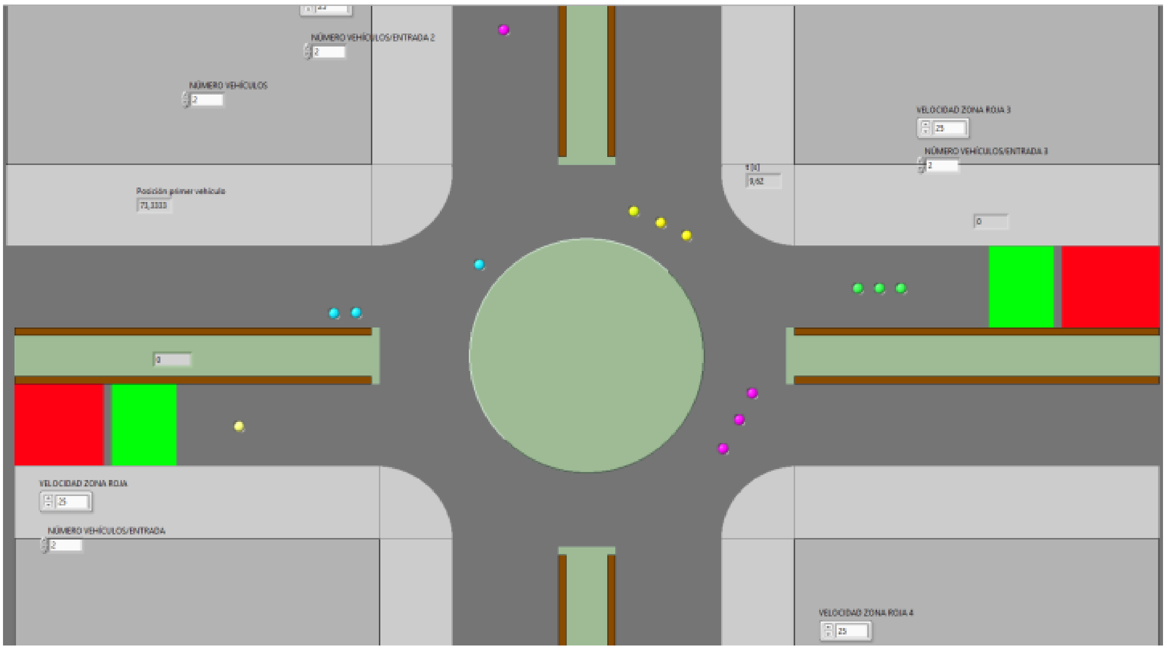
Picture 19. **Second version of interface**

The third version was improved in the appearance and controls for the user to make configurations more quickly and comfortably.



Picture 20. **Third version of interface**

This is the last improvement in the interface, making the vehicles the only ones to be shown, although they still have different ways to see if they match.



Picture 21. **Last version of interface**

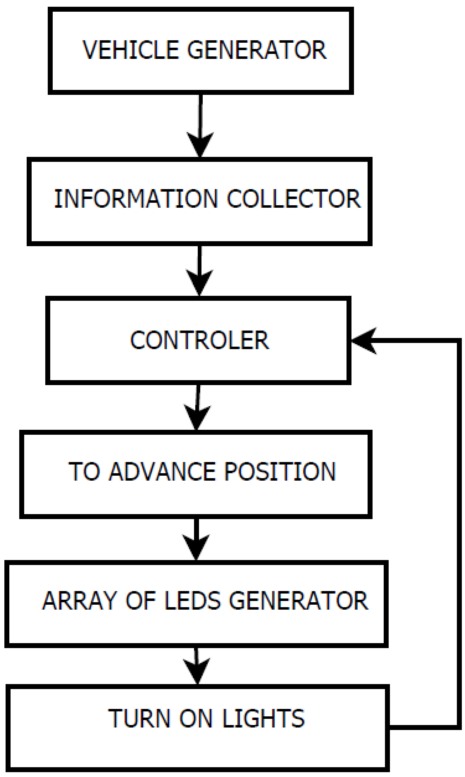
This format of representation, through LEDs, allowed me to have a great capacity of generation of vehicles without saturating the code since the generation of objects that moved on the screen would be harmful. The real dimensions of the simulation are 1.75

meters between each led, this being enough to show the distance between vehicles, although it is functional, if is required, I can double the number of LEDs to have greater accuracy.

5.4.2. Simulator code

As I said before, this has been the biggest workload of the project, there are more than 800 contacts developed, I am going to explain how they are distributed and what each module consists of. The modular code design allowed to replicate the code of one entry in three others, this means that each lane is independent and configurable, between these configurations, we can set the speed of circulation prior to the green zone, the speed they must circulate through the roundabout, the number of vehicles entering per entrance, the distance between vehicles and the probability of generation according to the type of vehicle.

There are elements that are calculated ideally to be able to perform the simulator correctly, even though they are not adjusted to reality, but it is an identical element for all cases, then does not make such a big difference, for example the speed changes, these have not a delay in the time, they are reached of immediate way when the order is given them when they go into the roundabout.



Picture 22. Block diagram that represents the order of code execution

5.4.2.1. VEHICLE GENERATOR

The vehicle generator, as we can see in figure 1.1. in the annex, this code generates a coded number, it has the information of the position where the vehicle is located, the speed, the size, the entry and the exit that it will take.

The size of the vehicle is conditioned by the data obtained already explained in section 5.4.1 and they are generated by a random value between intervals that provide that link between probability and quantity.

The output is also made randomly, in this case all having the same probability of being chosen.

The position is determined by the first vehicle generated plus its size plus the distance we choose to have between vehicles.

5.4.2.2. INFORMATION COLLECTOR

This part of the code allows decoding the numbers generated previously and to provide at the ends of the WHILE loop the information organized so they can be used at any stage of the execution. The code in figure 1.2. of the annex.

5.4.2.3. TO ADVANCE POSITION

The vehicles must respond to their speeds in a time interval that we have set in 0.2 seconds, following the equation of uniform rectilinear motion [1] as we can see in figure 1.4. in the annex:

$$[1]\quad x(f) = x(i) + v * t$$

This allows us to advance all the positions of all the vehicles with the only limitation that it does not attend accelerations as indicated in section 5.4.2, this occurs for each of the vehicles previously generated by that entry.

5.4.2.4. ARRAY OF LEDS GENERATOR

It initializes an array of Booleans with the same size of LEDs as its road, in this case they are 58. Each vehicle, as we can see in the code in figure 1.5. in the annex, is identified between two intervals, its front position and its position rear that depends on its size, to be able to have a greater precision when turning on the correct LEDs we resize the decimetres to meters multiplying by ten, this allows not to lose decimals.

Once taking into account this resizing, it is asked if the position of the LED is between the front and rear values of the vehicle, if the answer is true, it will generate an activated position. This principle is realized with all the other vehicles at the same time that we add them with OR gates and distinguish between the lane through it will exit. Generating in this way four different array with each vehicle of the 58 elements.

5.4.2.5. TURN ON LIGHTS

This part of the code, as we can see in figure 1.6. of the annex, is responsible for passing the signals stored in the array of each possible output to the LED indicators.

5.4.3. CONTROL

The objective of the control is to take the vehicle to the entrance when there is not going to be any vehicle. This forces us to calculate the vehicles that could be circulating at that point and find a free space where they can fit.

Once the times, when the entry position is occupied, have been calculated, I need to calculate the time when there will be free space. In case of not having immediate space, the vehicle will go to the tail of the last one.

The calculation of the best free space allows the vehicle to decelerate as little as possible and this improves the efficiency.

Once knowing the speed that must be applied to enter correctly, when this vehicle reaches 13 meters from the sensor, where the green zone is located, the indicator will light up to show the new speed must circulate until entering the roundabout, which is 20 meters away.

Then the calculation of times will be done again, they are common for all the vehicles of all the lanes, they should consult the times in real time. I solve this by creating local variables that saves cabling space. The entire code can be consulted in the annex in the control section.

6. START-UP

Taking into account the data provided by Etra Bonal, the work could be done in four weeks with a budget approximated to a normal crossing in Barcelona, so it would have an approximate price of 40.000€, plus the LabVIEW license, for those devices, where you install your executable, will cost approximately 4.000€. Finally, I estimate the price of the work in a total of 44.000€, in four weeks.

7. CONCLUSIONS

ACHIEVED GOALS

LabVIEW has proven to be up to the demands made during programming both in the design of the interface and in the control. My experience in solving innovative concepts has grown considerably along with my motivation to continue creating projects of this style.

After making tests of great duration and adjustments in the control, causing that they circulate until a total of 500 vehicles, I consider that the control is satisfactory, in spite of producing a 13% of partial unsatisfactory couplings of which 2% are fatal.

Partial unsatisfactory couplings are those that their the introduction will be satisfactory controlled by a human, while the fatal ones are those that the control points directly to a vehicle, large vehicles are that cause these types of variations impossible to circumvent. These tests have been carried out with a specific configuration of spacing between vehicles and concrete generation speed, with 2,160 vehicles per hour. Compared with the Ramp Meter that caused the total stopping of the vehicle, I consider that, taking into account that the vehicles controlled by my application reduces on average 55% of its speed, the energy saving is 45% greater than Ramp Meter.

As the first large innovation project that I do on my own, I find that the greatest amount of development is found in the developing and testing of the prototype.

FUTURE IMPROVEMENTS

As I have seen during the simulation tests, I distinguish improvements to be made in a short period of time and in the long term. Immediate improvements that I can apply is the way in which the detection of vehicles is done, in this project, I base myself in ideal conditions and an improvement in realism will allow to be more robust in variations derived from the acceleration. In addition, the limitation of only obtaining data from vehicles at 32 meters from the roundabout doesn't prevents intermediate variations, this would be solved by creating an image recognition of vehicles, determining their size, speed and position in real time, without making approximations.

The long-term improvements are related to the communication between autonomous vehicles and infrastructure, where these vehicles receive accurate traffic information and can be coordinated, avoiding jams and accidents in a perfect way.

POSSIBLE APPLICATIONS

This type of control can be applied in the efficient occupation of train rails, making them able to circulate indistinctly in both directions without causing accidents or delays, also when overtaking, setting a certain speed to overtake safely. These are just a couple of applications, but I'm sure we'll see more of them in the coming years.

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