Development of an Automated Guided Vehicle Prototype for Material Handling in an Aeronautic Environment

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Abstract

This project intends to be focused on the prototype development of an Automated Guided Vehicle (AGV) to be introduced within the components shop at TAP Maintenance and Engineering. This autonomous vehicle will perform the material handling task along the shop, currently done manually, towing the cart that transports the pieces following a magnetic tape.

The construction is made following the preliminary research and design done in the previous years. Firstly, the cart is built according to the design and different modifications are explored to make the coupling between cart and stands work correctly. In addition to this, the design of the group stands is also addressed. Next, the movement and control script of the AGV is developed using MicroBasic Lenguage. This code is, in turn, simulated with a software to verify the correct and safe operation of the vehicle.

In terms of hardware, the interface and connections among all the electric components is approached as well as the laser sensor configuration. The towing pins device that allows the attachment of the cart to the AGV is designed using electric lineal actuators. Moreover, the design of a two drive wheels configuration is explored as an alternative to the steerable wheel configuration initially selected.

Finally, the battery charging system is selected after comparing the different charging methods. The advantages and disadvantages of each one are brought face to face and the decision is taken based on several factors with different relevance for this application.

Keywords: AGV, Material handling, Prototype development, Movement and control script, Battery charging system

1 Introduction

In the manufacturing and maintenance frame it is important to optimize the processes to get the final product with the best quality not penalizing the costs and time involved, which implies being competitive and improving the market share. The customer wants it cheap and good and the company has to do efforts to be able to offer the final product in time with a competitive price and top quality. Thus, it seems essential to adopt strategies that allow this, and here it is where the continuous improvement philosophy plays a crucial role.

One of the most important tasks in this framework is the material handling, which has huge influence on the production process and potential profits. Material handling is a remarkable source of wastes. For many decades the handling operations has been done manually with workers carrying or driving vehicles transporting the material. Nowadays a lot of companies have decided to implement autonomous guided vehicles, best known as AGV to make this tasks without the need of relying in humans. An automated guided vehicle is a mobile robot that follows a path described by markers or wires on the floor, or it uses vision cameras, magnets, radio waves or lasers for navigation. The benefits are unquestionable since it reduces the labor costs in terms of salaries and taxes, increases safety and gives the possibility of working in hazardous environments for the human. Moreover the AGV does not need to respect work shifts since it does not get tired and distracted which implies a reduction in the number of errors committed. They are mostly used in industrial applications that required the material handling as well as in hospitals to transport medicines, food and bed linen [1].

The final objective of this project is to build a prototype of an AGV meant to work on the HP component shop at TAP M&E based on a preliminary design done in the two previous years by other students. The AGV introduces itself under the cart where the pieces are transported, and it activates two pins that allow to tow the cart. In a first iteration, what it is wanted to achieve is to start up the AGV following a closed path to do the distribution of the different pieces to be repaired in 4 different groups (Pneumatic, Hydraulic, Electrical and Fuel components). The AGV should make the reception and expedition operations in an autonomous way following a magnetic tape place on the floor and guaranteeing the safety of all the workers every time at the shop.

Therefore, in order to reach this objective it will be necessary to build both the reception and expedition stands and the vehicle itself, which in turn consists in a cart that carries the trays with the parts and the AGV towing it. All this elements have been already designed but not tested, thus the prototype will be constructed following the preliminary design and testing if it works or not, making modifications of the design on the go as needed. The structure and mechanisms of the stands and the vehicle are built using the TechnoLean materials available on the shop provided by Quimilock, which is the main supplier [2].

In terms of safety, the AGV must be able to recognise obstacles that could eventually appear in the middle of the path and stop, avoiding crashing into them. Furthermore it must count with an emergency stop button to shut down the AGV whenever an emergency occurs and stop automatically in case of sensor failure.

2 Material distribution system

To get started, the efforts have been focused on the construction of the cart and the reception stations based on the design done in [3]. Unfortunately, the locking system is tested simulating a contact and it did not open unless a strong force is applied forcing it. The TE connectors responsible of providing relative movement between the tubes forming a ”T” are not ideal since there is not a pure rotation around one axis but an additional not wanted tilt around the other two axis, direct consequence of the momentum produced by the contact force which is misaligned from the tube where the TE connector is placed. This tilt blocks and complicates the natural rotation around the main axis, thus the locking system gets plugged while trying to open (see Figure 1).

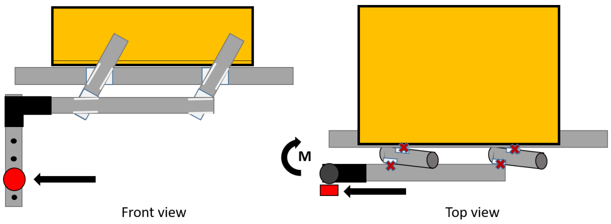

Figure 1: Scheme of the locking system aperture problem. The red crosses represent the block in the TE connectors rotation axis

Once it is known that the designed locking system does not work as it was suppose to, the search of an alternative seems obligatory. Several alternatives have been tested in a trial and error process before coming up with the final idea. All the failed solutions as the original one meant to keep the multi-usage of the cart in all the groups. Selecting the position of the adjustable roller, each cart shelf could be used for every group station giving to the cart the possibility of eventually carrying trays to one single group using all the shelves for that group. Unfortunately, it was not possible to find a solution that solve the problem of the locking system blockage, therefore it was decided, for the sake of the project feasibility, to change the concept and assign each of the cart shelves to one specific group. Now the four cart shelves have different heights (see Figure 2 and Figure 3).

The difference of level between the two upper shelves (same for the two lower ones) is established in 95 mm to avoid the activation of the shelves stoppers in wrong groups. The station ramp passes just above the stopper of the group 2 cart shelf avoiding any contact. The same happens when a tray is delivered to group 3. In addition, during the group 2 and 4 deliveries the activation ramp will make a slight contact with

Figure 2: Cart shelves

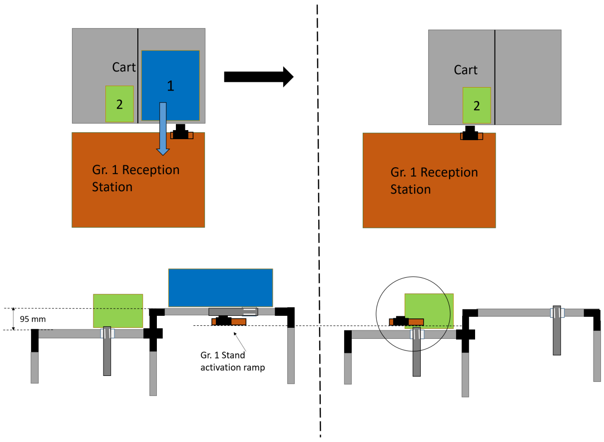

Figure 3: Scheme of a tray delivery to group 1

group 1 and 3 cart stoppers partially opening them but this shelves will be already empty. The station activation ramp consists in a TechnoLean TD connector that stands out making contact with the cart shelf stopper. Since the contact is produced in the stopper tube itself the problem of the momentum disappear and the TE connector does not tilt not getting stuck.

Regarding to the reception station, it was important to design a stand that allows to receive and keep several trays waiting to be picked up and repaired. Sometimes when a tray is placed in the reception stand, immediately a worker picks up the tray to repair the pieces. However, especially in some groups, more often than not, the trays remain a certain time in the station awaiting to be taken. Since the cart will always make the tray exchange in the same shelf, in order to guarantee that several trays fit in the stand it is necessary that each delivered tray moves automatically following a series of inclined multi-directional rollers rails occupying the empty spaces of the station shelves surface.

To understand better this design, schematic pictures of the delivery process between the cart and the stations 1 and 2 are presented in Figure 4 and Figure 5 respectively. The change of direction of movement in 90° is possible thanks to the gravity, the trays fall by its own weight and start to follow a series of rails perpendicular to the initial ones.

The group 3 reception stand is exactly like the group 1 stand and the group 4 equal to the group 2 stand but of course with different height given by the correspondent cart shelf level.

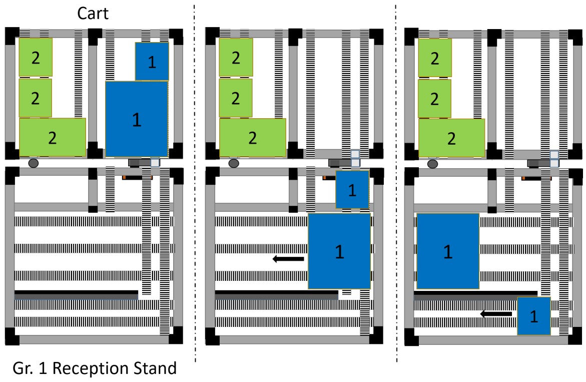

Figure 4: Scheme of the reception process in group 1 (Top view)

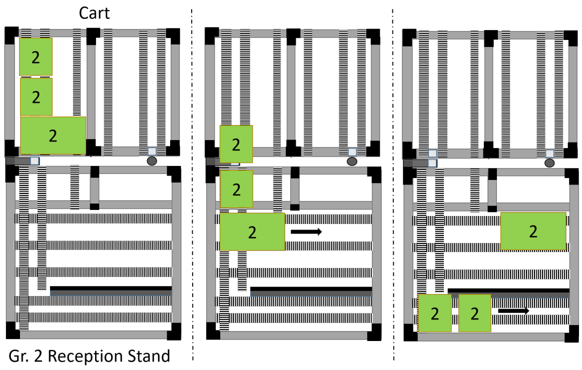

Figure 5: Scheme of the reception process in group 2 (Top view)

3 AGV development

The AGV moves following a closed path that starts and ends in the reception and expedition area and it goes across the shop performing the reception and expedition operations on each of the four groups. The navigation system is magnetic tape guidance. The sensor mounted on the AGV detects the presence of the magnetic tape and this information is processed in the motor controller that, according to the programming script implemented on it, sends steering commands to the wheels. For this application, it has been decided to connect the sensor MGS1600GY to a FBL2360 dual channel motor controller, both by Roboteq company. All the computation is done in the motor controller using the MicroBasic scripting language [4].

3.1 AGV script development

The code is developed in a way that allows the AGV to follow the magnetic tape and stop on each station for a brief time to perform the trays delivery or pick up besides going and stopping at the charging station when the battery is low. In order to make the AGV stop in the different group stations two magnetic markers will be placed on both sides of the path being the right one ahead. When the sensor detects that both markers are present, the AGV stops and it starts the countdown to resume the motion. During this brief pause time the trays are exchanged between the AGV cart shelf and the group stand.

To identify the Base position, where the AGV is meant to start all the routes, and the Battery Charging Station, both in the Reception / Expedition room, it is necessary to place the markers in a special way, different from the one used for the stations stops. It has been decided to place an unique left marker and short right markers separated, forming a dashed line (Figure 6)

Figure 6: Group station (left), Base position (middle) and Charging station (right) markers

The code is build in a way that allows to count how many right markers there are and thus identify whether the AGV is at the Base position or at the Charging Station. When the AGV has fully charged the batteries in the charging station, it automatically returns to the base position. The battery charge status is known monitoring the battery voltage.

Whenever the AGV approaches to a fork or merge it will take the left or the right path depending on whether the last marker detected was on the left or right side. Nevertheless, in function of the type of operation, the AGV must follow a different path whether it is performing a reception or an expedition operation. Therefore, in the two points where the path is split for each one of the operations it is necessary to place a marker similar to the ones in the Charging Station and Base but this time with only two right markers.

In terms of safety, the AGV must comply with some requirements like stopping when an obstacle is detected by the laser sensor or any sensor fails. There are two kind of fields detected by the laser sensor, the warning field and the protection field. Whenever an object is detected in the warning field the AGV must emit an alert sound, however if the obstacle is detected into the protection field the AGV must stop immediately and wait for the blockage clearance. Once this happens, it resumes the walk after a few seconds ("ResumeTime"). On the other hand, whenever a sensor stops working the AGV immediately stops.

The AGV tows the cart that transports the trays with the aid of towing pins. They are retracted when the AGV stops in the base and deployed again when a new route is started after pushing the "Go Button". They keep deployed until the AGV returns to base. There is a time delay ("PinsTime") between pressing the button and starting the movement to make sure that the pins have enough time to deploy before the AGV starts walking. The pins mechanisms consist in a pair of electric linear actuators connected both to digital outputs 1 and 2 of the motor controller.

Finally, concerning the control of the AGV it has been tested two ways of control (Proportional control and PID). The sensor outputs a value that is the tape's distance from the center of the track. This information is then used to correct the steering. The further the track is from the center, the stronger the steering change. For this application, since the path is simple to follow and does not contain any sharp or consecutive curves, and the AGV will move at low speed, it is expected that the proportional control is enough to have a satisfactory control. However, this will be verified in the test as well as the control parameters tuning.

In order to check whether the code architecture makes the AGV perform the desired task, the script is simulated in a free AGV simulator software provided by Roboteq [5]. This simulator gives the possibility of sketching the path, place magnetic markers wherever necessary and configure the AGV characteristics.

3.2 AGV building

The different electrical components that define the AGV are presented in Figure 7 and the general view of the AGV structure with the main components is shown in Figure 8.

However, it is also explored the possibility of using a two drive wheel configuration instead a single steerable drive wheel configuration. It is considered that the most suitable option would be the use of the Benevelli DD1 Serie [6] because its diameter is similar to the steerable drive wheel and it consists in a complete assembly of the two wheels unlike other considered models.

Table 1: AGV electric components

Component	Company and model	Amount
Magnetic Sensor	Roboteq MGS1600GY	1
Laser Range Finder Sensor	Sick S3000 Standard	1
Steerable Drive Wheel	C.F.R MRT05.D0101	1
Towing Pins	Electric Linear Actuator (Company: N/A)	2
Motor Controller	Roboteq FBL2360	1
Battery	PowerTech PowerBrick-LiFePO4 12V 70Ah	2
Go Button	N/A	1
Emergency Stop Button	N/A	1
Operation Switch	N/A	1

Figure 7: AGV electric components

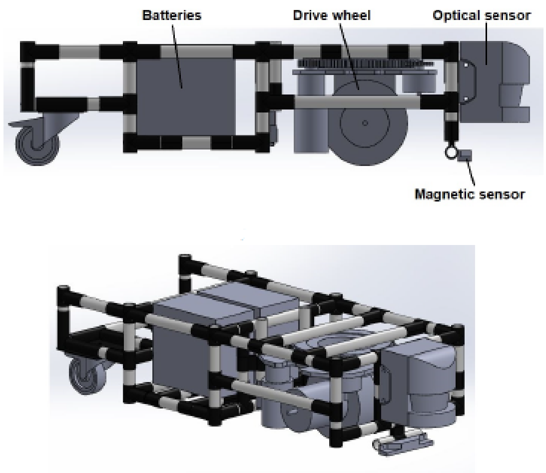

Figure 8: AGV electric components

The laser range finder sensor is configured with the SICK Configuration and Diagnostic Software (CDS) downloaded in the manufacturer website [7]. The main feature of this software is that it allows to customize the dimensions and shape of both, the warning and protection fields of the sensor. In this way, whenever an object enters in any of the zones, the output signal (OSSD) is switched and sent to the controller connected to the sensor. If the obstacle is detected in the warning zone, the AGV will emit an alert sound, and if the blockage is found within the protection zone, the AGV stops immediately until the obstacle is removed.

Regarding the structure of the AGV, it is designed to support all the electric and mechanical components as well as offering a correct coupling with the cart. Again, it is completely built using TechnoLean materials which provides a wide flexibility to do modifications easily if necessary.

The steerable drive wheel is easily fixed to the structure through four screws M10 that pierce the tubes located just above the wheel attaching the wheel to them as shown in Figure 9.

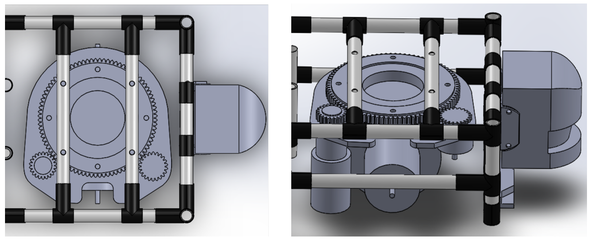

Figure 9: AGV 3D model steerable drive wheel attachment

In case of changing the single steerable drive wheel to the 2 drive wheels configuration some modification must be done in the front part of the structure. The length is increased and the width decreased to align the support tubes with the wheels holes allowing the fastening of the wheels assembly to the structure through M8 screws. This new AGV structure is meant to fit the Benevelli DD1 series drive wheel, nevertheless, it could also be used to attach the other wheels models making height adjustments of the support tubes as well as modifying the width and length of the front part structure as necessary. The design of the AGV chassis for the 2 wheels configuration is presented in Figure 10.

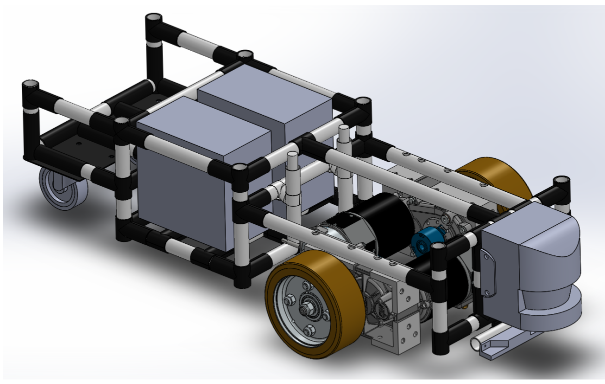

Figure 10: Two drive wheels configuration, AGV 3D model perspective view

4 Charging system

The charging methods for AGV batteries can be classified essentially in two types, contact and contactless. The contact charging methods, as its name indicate, works making direct contact between the battery terminals and the charger. For AGV applications, these systems are typically compounded of two parts. A base plate placed outside of the AGV fixed generally to the floor or any lateral support and connected to the battery charger, and a current collector which is mounted in the AGV connected to the battery terminals. When the collector makes physical contact with the plate, the current passes from the charger to the batteries.

The contactless charging makes use of the magnetic induction to charge the batteries not requiring physical contact between the battery terminals and the charger. The system consists in a transmitting unit and a receiving unit. The transmitter is connected to the AC electrical grid and contains a coil that generates a magnetic field when the AC current passes through it. Next, this magnetic field induces an AC current in the coil contained in the receiver existing an air gap between both coils. This AC current is converted to DC by a rectifier and smoothing circuit and regulated before supplying the batteries.

It also exists an advanced wireless charging technique called magnetic resonance, that even though it is based exactly on the same principle than the latter, it increases the alignment flexibility avoiding the severe efficiency drop for larger gaps and misalignment between coils [8].

To decide which method is the most suitable, it will be taken into account 4 factors (efficiency, alignment/ air gap flexibility, costs and maintenance). Next, it is assigned a specific weight to each factor in function of its relevance. After all these, it turns out that the best charging methods for this application is the contact charging because it presents the highest efficiency, a moderate alignment flexibility, the lowest cost and it does not require a constant maintenance effort due to the high resistance to friction wear of the plates, and sweeper accessory that can be attached to the collector to keep the ground plate cleaned, free of dust and particles each time the AGV pass over the charging station.

The model selected is the Roboteq Robopad charging system that uses magnetic contacts to make contact instead of conventional spring contacts (Figure 11). This increases the number of cycles that the charging device lasts due to the reduction of accumulated friction wear [9].

The attachment of the collector to the bottom of the AGV chassis is done through four M4 screws, however some modifications of the structure must be done to fix the collector. The design is presented in Figures 12 and 13 for the steerable drive wheel configuration. For the two drive wheels configuration the design of the attachment structure would be similar adapting the tubes dimensions.

Note that in order to avoid any possible rotation around the perpendicular axis of the support structure, it can be added a 90x64x3 mm metallic plate used as joint between the two parallel tubes that support the collector through four M4 screws.

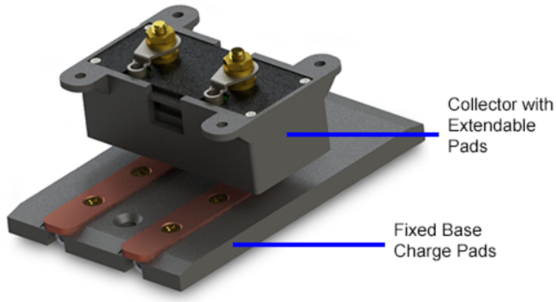

Figure 11: Roboteq Robopads [10]

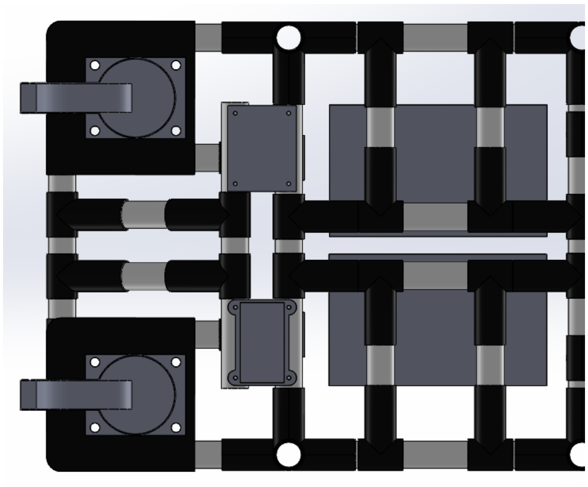

Figure 12: AGV Bottom view detail

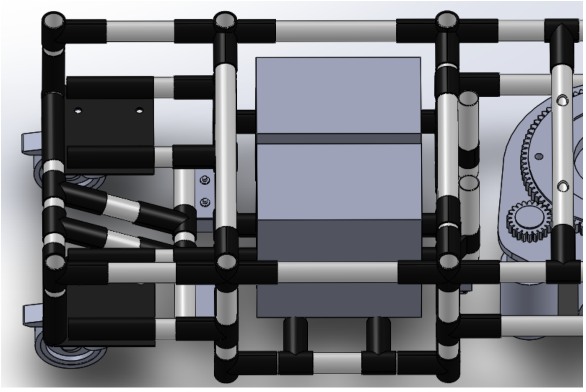

Figure 13: AGV Perspective detail

5 Conclusions

- The first design of the cart did not offered a correct functionality in terms of coupling between cart and group stand causing problems in the opening of the stoppers mechanism that allows the trays exchange. Therefore, after testing several concepts and solutions, a simpler stopper mechanism was implemented requiring that each one of the four shelves was assigned unequivocally to one group.

- The design of the reception group stands has been carried out in a way that makes them capable of storing several trays.

- The script that commands all the movement and control of the AGV has been written using MicroBasic language and simulated. Since the simulator does not allow to configure the AGV with only one steerable drive wheel, the results of the simulation are valid in terms of movements and task performances, but not in terms of steering control. In order to get a better match up between the simulations outputs and the real life, it is also proposed the use of a new AGV configuration consisting in two driver wheels instead of one which can be perfectly set in the software.

- The towing pins device consists in two electric lineal actuators connected to two simple relays that allow the inversion of the motors polarity in function of which one of the two digital outputs is active. The rod of the actuator is deployed whenever the AGV is running allowing the cart towing, and retracted when the AGV is stopped in the base.

- The contact charging method has been selected above the magnetic induction and magnetic resonance methods because of presenting the highest efficiency besides enough alignment flexibility and not requiring a periodical maintenance. It is also the cheaper and simpler option.

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