Robox notes

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Robox motion control

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To manage an AGV using Robox products, 3 components are needed: a map, motion control and plant specific logic.

Maps are drawn using RAT software then converted to an ASCII file with *.map* extension. This file is used by other two softwares: AGV manager and RDE.

AGV manger has two main parts: script and core. The specific logic of a plant is written in a script using XScript language, and given to the core that execute it. The core handle also the communication with the motion controller and eventually a plant PLC or database.

RDE is Robox IDE for motion control programming. The map is compiled by ICMap and read by the RTE. This part will be explained in other chapters.

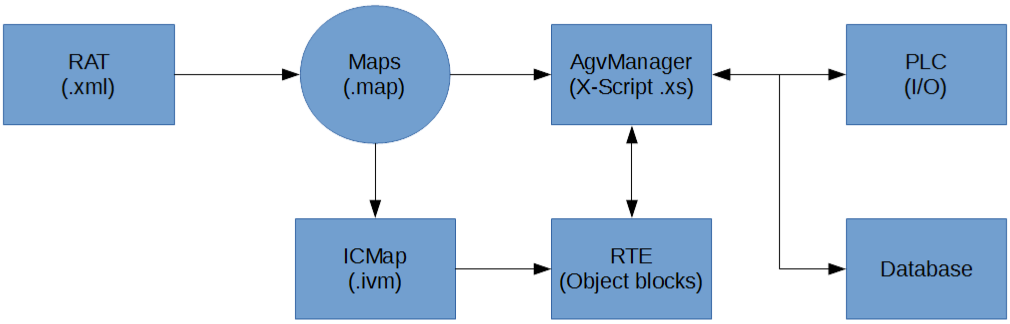


Figure 1.1: AGV block diagram. RAT give a .map file as output. The map is read by AGV manager. The map is comiled by ICMap then read by RTE. AGV manager may communicate with a PLC or a database as an interface to the plant IO, and with RTE for motion control.

In the following chapters we will explain Robox software in order to draw a map and assign missions to Agv. Three softwares are needed : RAT, AgvConfigurator and AgvManager. Note that maps can also be edited by a text editor. AgvConfigurator is a part of AgvManager and are installed togethers.

2. RAT: Robox Agv Tool

2.1 RAT

RAT is a CAD software, fig.2.1, aimed to design maps and convert them into a formatted ASCII file with *.map* extension. RAT save the created files as *xml file*. A map can also be created using a text editor following some rules.

RAT can load *dxf* files as background, that can be used as a guide to design the desired map. Mainly RAT have lines, points, vehicles. These component will be explained later.

In the properties of the project some settings have to be changed in order to change the behavior of the AGV motion, for example *Trasversal navigation* is set by default to *disabled*. When it is enabled the AGV can move trasversally to a line, and options will be added to points. If some point's options are not visible, check if this property is not set to *enabled*.

2.2 Map

A map is composed by lines, points, crosses and vehicles. During the design of a map some constraint and configuration can be set. For example speed, direction of movement. The main property of a vehicle is the dimension. The length and width can be set here.

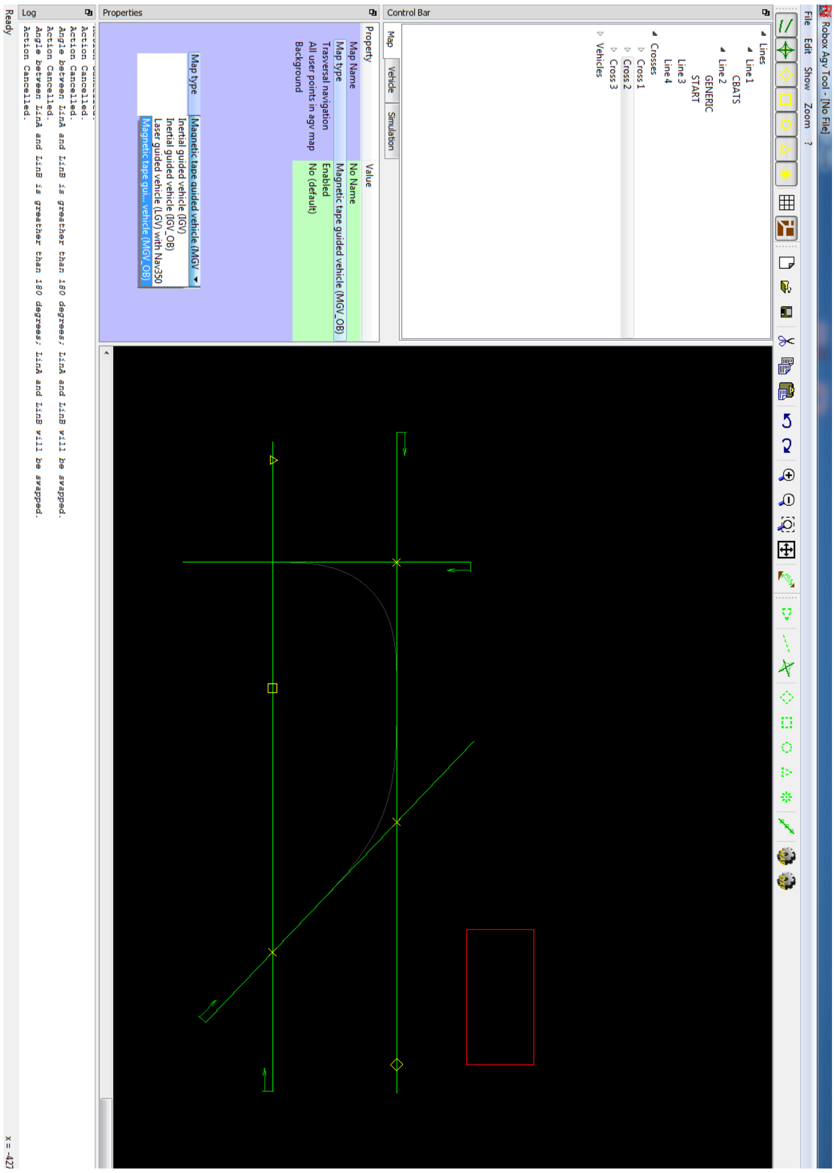


Figure 2.1: RAT main window

2.2.1 Vehicle

We can define the number of vehicles present in a plant, their shapes and dimensions. In our discussion we suppose a vehicle have an orientaion, a coordinate systems attached to it. We can imagine the vectors (arrow) $\overrightarrow{BF}$ and $\overrightarrow{RL}$ as coordinate system axis, fig.2.2, i.e. $\overrightarrow{x} = \overrightarrow{OF}$ and $\overrightarrow{y} = \overrightarrow{OL}$.

If we have more than one Agv, it is convenient to set different colors, we can do it changing the property *Enabled Colour*. The default value is white $(255, 255, 255)$.

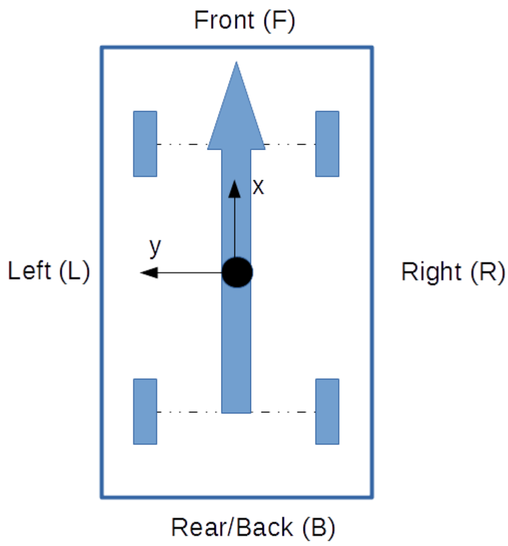


Figure 2.2: Vehicle orientation

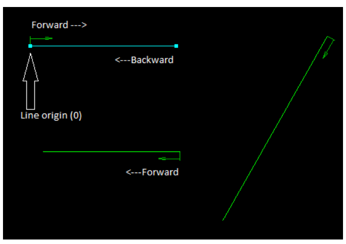
2.2.2 Lines

A line have mainly 2 properties, beside its location and origin fig.2.3b. Navigation direction and vehicle orientation. A line have to be seen as a vector, $\overrightarrow{L}$. For example a vector $\overrightarrow{OX}$ has opposite direction of vector $\overrightarrow{XO}$, note that $\overrightarrow{OX} = -\overrightarrow{XO}$.

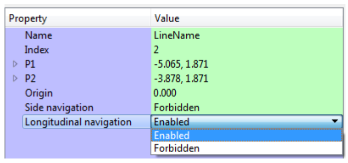
Two directions of motion are allowed: Forward and backward. Forward direction is shown by the arrow on the line, that is the positive movement, from O to X represented by $\overrightarrow{OX}$.

The vehicle can move longitudinally fig.2.4 to the line, i.e. $\overrightarrow{BF}$ parallel to the line, or transversally (side navigation), i.e. $\overrightarrow{BF}$ perpendicular to the line fig.2.5.

Precisely a line is a vector. The first point drawn P_1 (first mouse click) define the origin of the vector, the second point P_2 determine its direction. So the line is defined as $\overrightarrow{P_1P_2}$. The origin can be moved changing the parameter origin, when it is different from zero we can see the arrow on the line move, the position of the origin is calculated always from P_1.



(a) Line or vector. Direction of motion



(b) Line property. Navigation type can be set : side, longitudinal or both

Figure 2.3: Map line

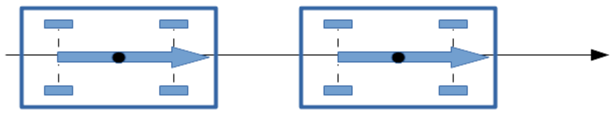


Figure 2.4: Longitudinal navigation. BF parallel to the line.

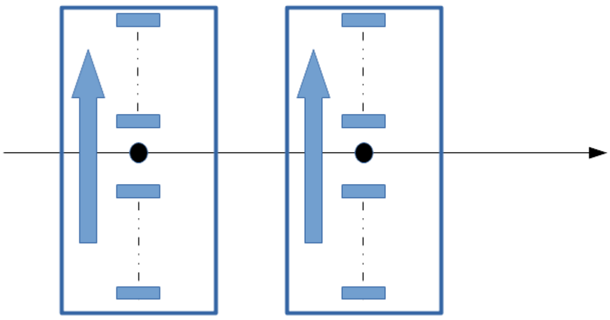


Figure 2.5: Side or traversal navigation. BF perpendicular to the line.

2.2.3 Generic point

There are 6 kinds of points as shown in fig.2.6. In term of object oriented approach we may say that all points derive from the base class Generic point. Those points share the following basic properties: Quote (position on the line), speed of the vehicle while crossing the point, direction (as a reference the line where the point is placed) and orientation (referred to the vehicle).

Genric points are used mainly to build the path of the vehicle. It is not necessary to assign a code to a generic point. AgvManager assign codes to Generic points that don't have one.

The following discussion can be applied to all kind of points, that have the properties direction and orientation (generic, user, cross, magnet, start, battery).

There are three allowed directions to approach and leave a point: Forward(F), Backward (R) and Anydirection (X). The allowed direction of point e.g.P_1 is meant as the direction of motion of the vehicle starting from this point toward another point in the positive direction of the line.

For example, if we set the allowed direction of point P_1 to Forward , and we want to move from P_1 to point P_2 placed at a coordinate greater than P_1, the motion is allowed. But the motion from P_2 to P_1 is not allowed. The direction in point P_1 control the direction of motion starting from itself toward positive coordiantes, fig.2.8.

The allowed orientation is referred to the vehicle fig.2.2. A point have 7 allowed

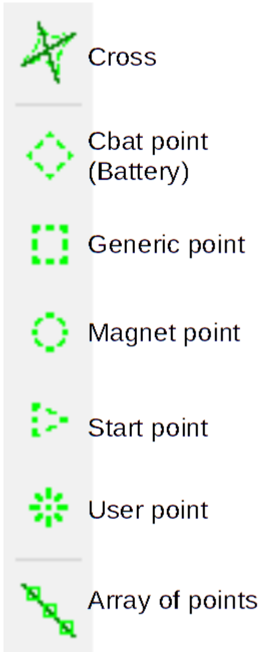


Figure 2.6: Kind of points

orientations. For example if the Front orientation is selected, the vehicle when is moving on the line, $\overrightarrow{BF}$ have the same orientation of the line $\overrightarrow{L}$. A Front orientation on point P_1, mean that the vehicle when moving from P_1 to positive coordinates the orientation of the vehicle is Front.

Semaphores can be created using any points except magnet point. When *semaphore index* is 0, there is no semaphore defined. When the index is positive the point define the semaphore start, when it is negative the point define semaphore stop. The semaphore is a rectangluar area, with width define by the parameter *semaphore width*, and length defined by the position of the start and stop points.

Speed property????

Can also be created array of points of a selected kind on a line.

2.2.4 User point

User point are like generic point, but they are associated to operations. For example, loading and unloading operations can be associated to user points. Information about the operations done on user points can be written on a database.

A user point should have the code property not empty, but a generic point code could be empty. A point belong to a line, if we have for example a matrix of points and lines, let's suppose the points belong to the horizontal line, if we need to move vertically from a

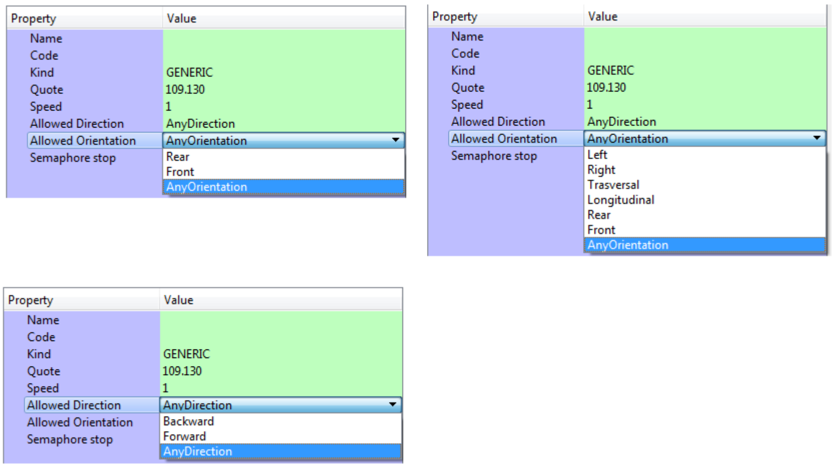


Figure 2.7: Generic point property

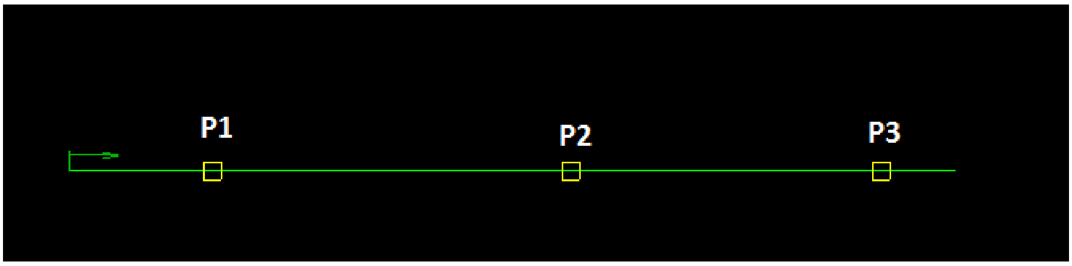


Figure 2.8: Line from left to right. P1 Forward direction, P2 Backward direction. Motion from P1 to P2 is allowed, from P2 to P1 is not allowed.

point to another, we can't do it, we need a cross point.

User kind ???????????

Side ?????????????

2.2.5 Battery point

CBats are battery points, i.e. charging station position. This point have the properties kind, index, side and the properties that derive from a generic point fig.2.10b.

CBats Kind ???????

Side ????????????

Display ?????????????

2.2.6 Magnet point

A magnet point have the similar properties as a generic point, but is not used for path construction. A magnet point is used for position adjustment and reference. Every magnet point should have an Rfid code, this code must be unique.

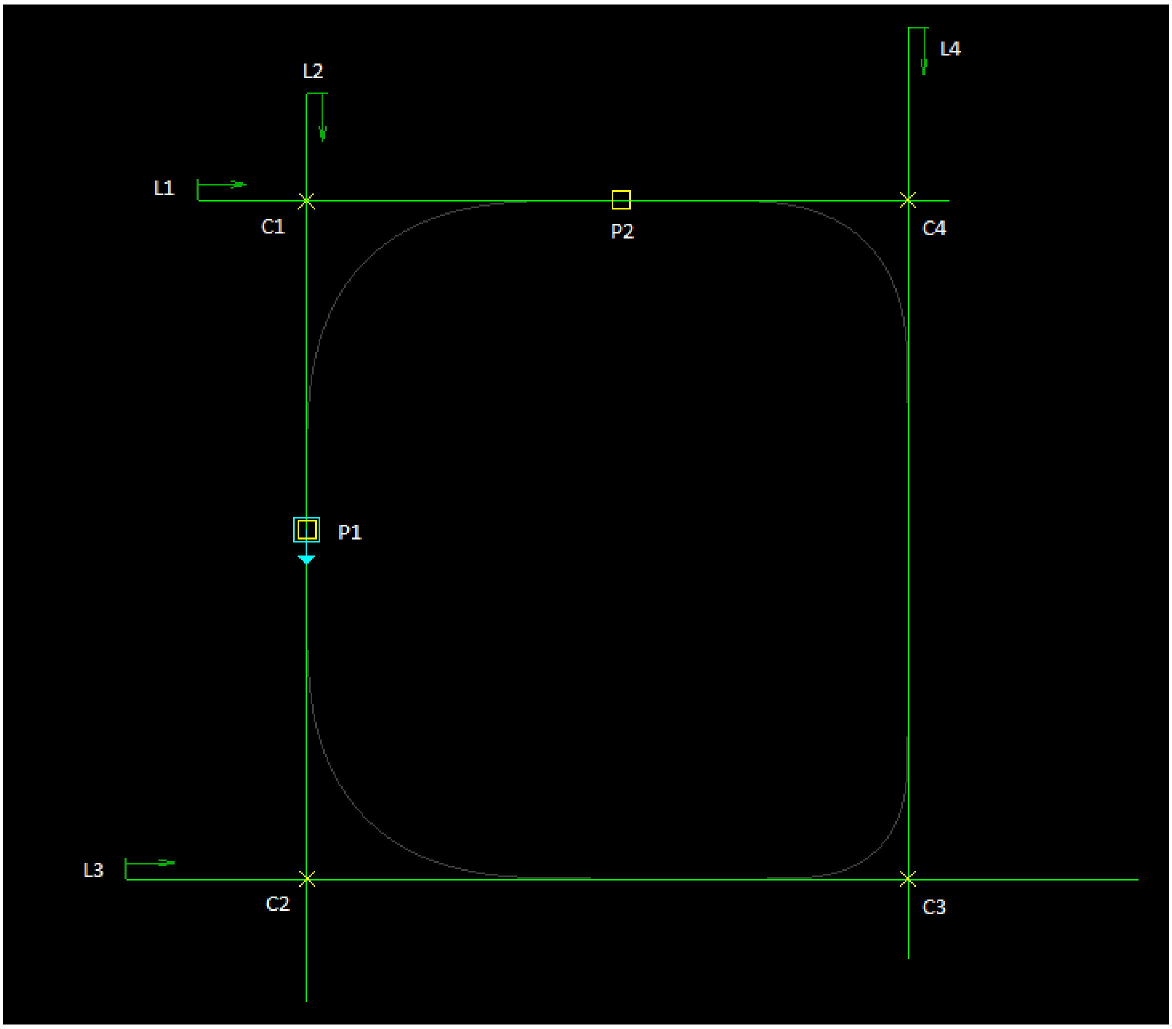


Figure 2.9: Point allowed direction. P_1 allowed direction is set to Forward. Motion from P_1 to P_2 crossing C_1 is allowed, because in C_1 the direction is not restricted, and because P_2 is not in the growing coordinate starting from P_1.

Side offset ???????

Magnet type ???????

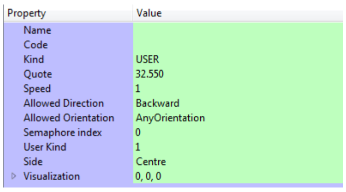
Forward mode ?????????/

Backword mode ??????????

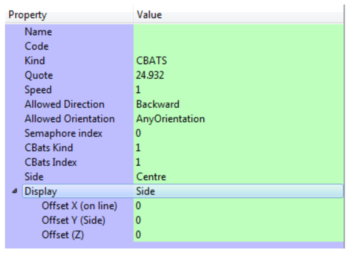
A magnet point must be installed at 0.5 m from a curve. For example if we have a cross of type curve, and 1 meter of takeoff distance, 2 magnet points have to be installed at least at 1.5m from the cross 2.11.

2.2.7 Start point

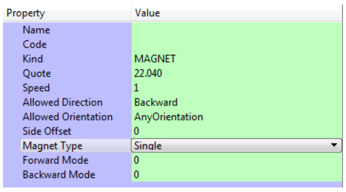
A start point is used as a home reference for a vehicle. A vehicle, once turn on, doesn't know his absolute position. Start point, associated with magnet point can be used to



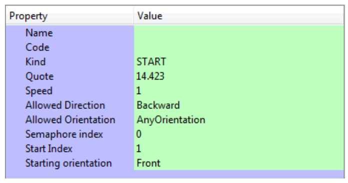
(a) User point properties



(b) Battery point properties



(c) Magnet point properties



(d) Start point properties

Figure 2.10: Map points

establish the position of a vehicle. In one map we may have more than one start point for one vehicle, pay attention to set the property Start index that should be unique number. If the index is not unique for start points RAT doesn't give any error (like for user points), but AgvManager will give an error when loading the map.

A reference position is composed from one start point and 2 magnet points. The position (quote) of the start point should be the same of one of the 2 magnet points.

Starting orientation ??????????

2.2.8 Cross

A cross is the intersection of 2 lines. An intersection have 4 quadrants. You can establish permission for vehicle in one or more quadrants. Three kinds of permission are available: Forbidden, curve and rotation fig.2.12.

A curve can be of 2 different types: 0- Odometric curve and 1- Tape curve with 3 segments.

Divieti is an 8 bit mask, the first 4 bits indicate the allowance of passing from line A to line B, and the second 4 bits indicate teh passing from line B to A.

Occupable indicate if the quadrant is occupable, when the agv rotate around itself, if the value is yes, the agv can cross the quadrant while rotating. If all 4 value are no, for the 4 quadrante the agv can only rotate the wheels is the passage mode is rotation.

Under the fields, points on line A and B, we can set the allowed direction an orientations for each line.

Override angle??????/

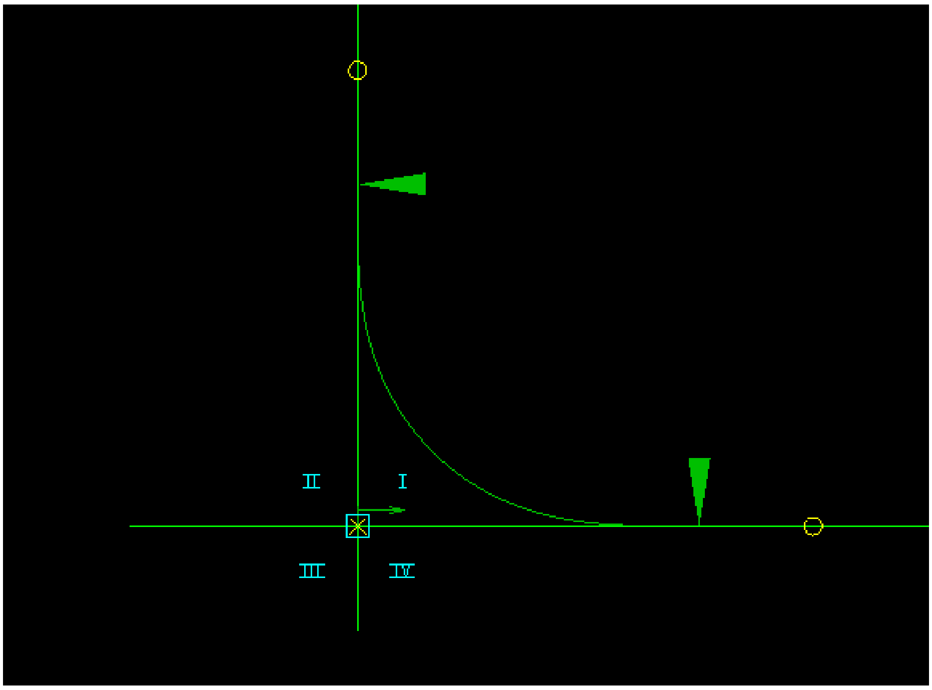


Figure 2.11: Two manget points should be place at least 0.5 meter from the end of a curve.

2.3 Tips

1. A reference point is composed from a start point and 2 magnets.
2. A curve should have 2 magnets placed at least at 0.5 meter from the end of the curve fig.2.11.
3. User points and generic points should be placed after the magnet points that form the curve fig.2.13.

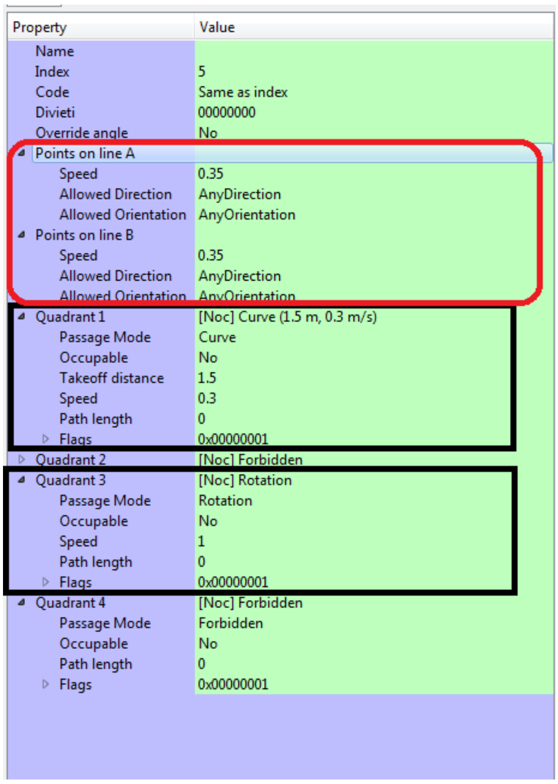


Figure 2.12: A cross is a point that joint two lines. It behave like a point on every line, orientation and direction can be set for every line independently.

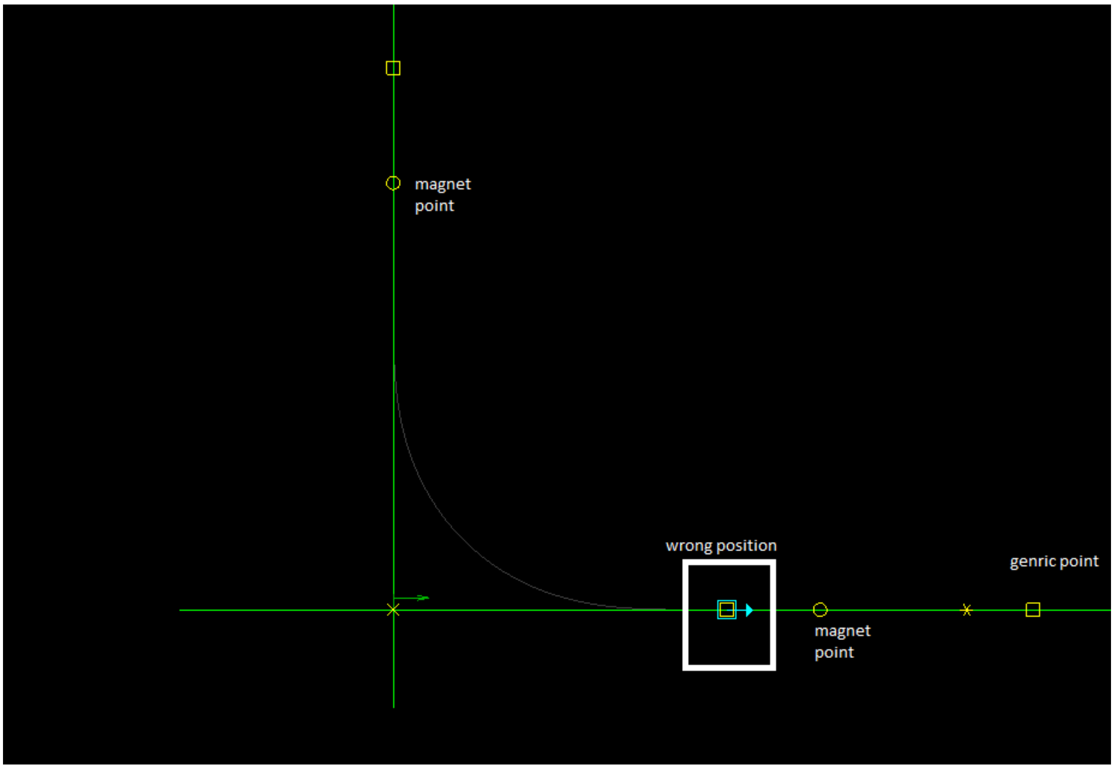


Figure 2.13: Generic points and user points should be placed outside a curve, i.e. after a magnet point.

3. AGV Manager

3.1 Overview

AGV Manager have 2 software components: AGV manager it self and AGV configurator. In AGV configurator are set some parameters like the map file directory, script directory, communication with the AGVs controllers, PLC communication and IO definition, database communication, emulator enabling, etc.

AGV manager will load the parameters set by Agv configurator, and main execute the script written for the specified plant. In AGV manager can be shown the map and motion simulation and modify the script. The script is written in XScript language (Robox scripting language) and executed by AGV manager.

3.2 Installation

The installation of AgvManger is straightforward, like any program in Microsoft Windows. AgvConfigurator is installed automatically with AgvManager.

In order to get the report from AgvManager a database should be installed. You can install MySql community version.

Once installed, a schortcut to AgvManager and AgvConfigurator have to be done. In the properties of the application, in Start in put the location of the folder where your projects are located, fig.3.2.

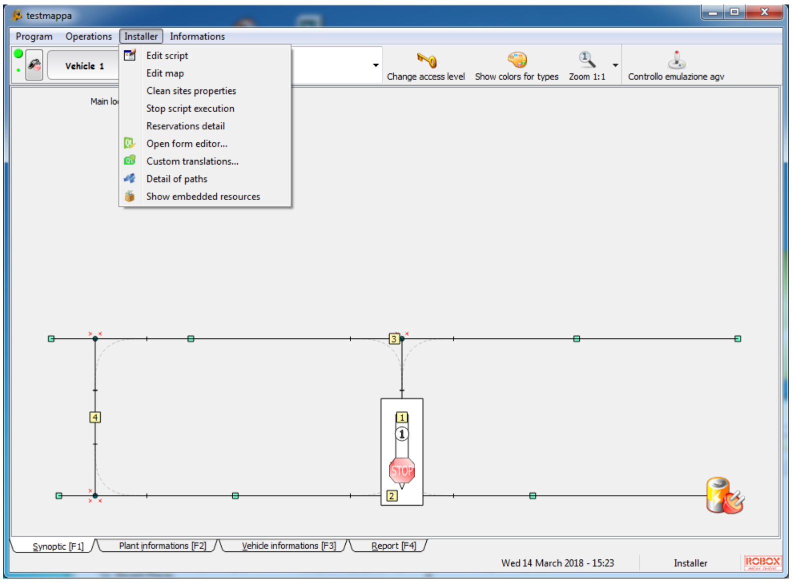


Figure 3.1: AGV Manager main window

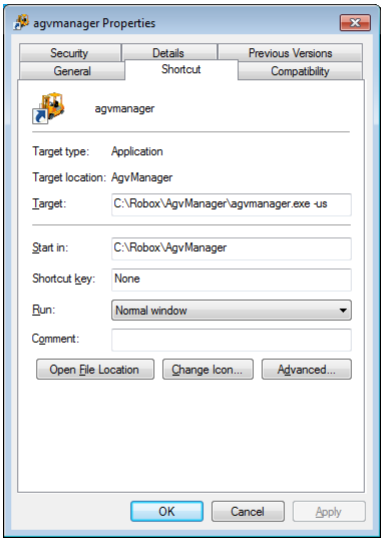


Figure 3.2: Application properties: Change the "start in" field to your projects directory

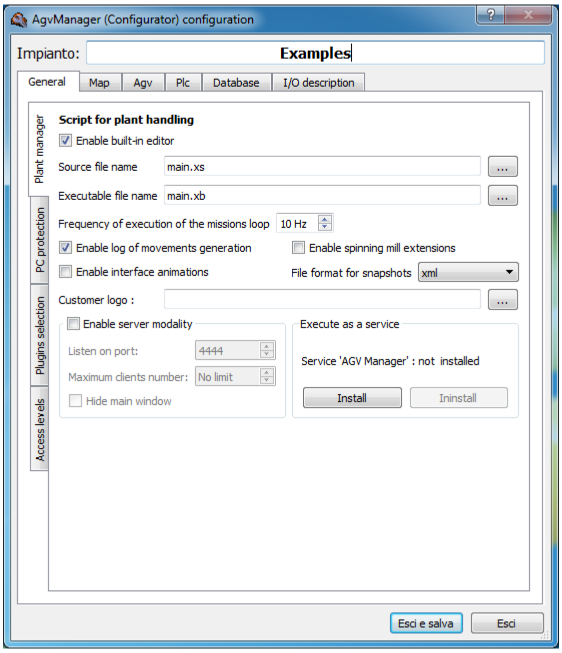


Figure 3.3: AGV configurator. General tab, where the *.xs* script file is selected. The script have to be created by an external editor. It is enough to write the name of the executable file with .xb extension, when AgvManager comple the xs file, the xb file will be created automatically.

3.3 AGV configurator

AGV configurator is a standalone program that create a configuration file *.fdoc* for AGV manager. From AgvConfigurator you can select the script to be executed by AgvManager fig.3.3, select the map fig.3.4 and agv 3.5 and plc communication.

Project folder should be placed in the directory specified in the field Start in of the application properties, otherwise it will not work. By default the start point of the application is its installation directory.

The script file should be in the first level of the project folder, it can't be placed in subdirectories, for example appStartDir/Project01/scripts/main.xs is not allowed, it should be appStartDir/Project01/main.xs.

3.4 AgvManager interface

AgvManager have one menu bar, one tool bar, one status bar, map visualization and different tabs [Fx].

In the tool bar, fig.3.6, we can find the button: Vehicle status, Commands insertion, Access level, color type, Zoom, Agv emulation, user define forms.

In the status bar we can see some message from the script, date and time, and current

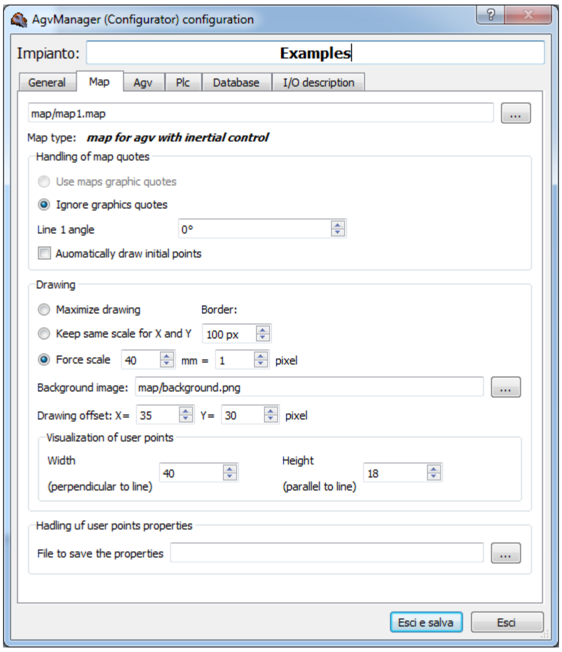


Figure 3.4: AGV configurator. Map tab, where the *.map* file is selected. In order to view the user point, you have to set the width and height of it, otherwise user points are not viewed. It is convenient to represent user points as rectangles, not squares.

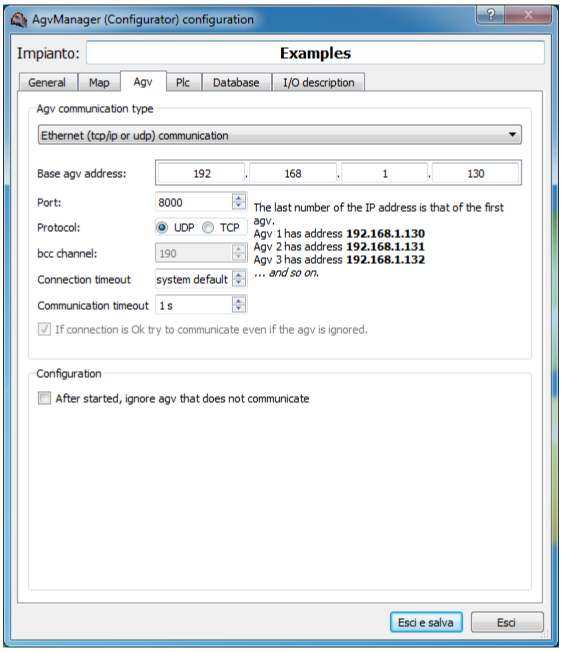


Figure 3.5: AGV configurator. AGV tab, where communication parameter with the AGV are set.

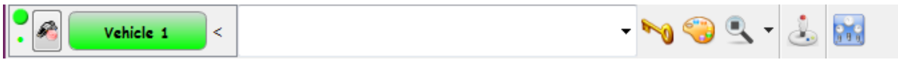


Figure 3.6: AgvManager tool bar

access level.

3.4.1 AGV emulation

If the flag *emuagv.dll emulazione agv* in AgvConfigurator, we can emulate the AGV in AgvManager. The windows of the emulation can be opened via the button *Controllo emulazione agv*.

The window in fig.3.7 shows the status of the Agv, groupbox *"Stato"*, where are viewed the 32 Vehicle Status flags (XVehicleInfo.uStatus). The first 4 flags are written by the vehicle and the others can be defined by user. The first 4 bits (flags) are:

- Power enabled
- Execution command
- Charging battery in progress
- Load present, or Unit load present

These flags correspond to:

```
// Vehicle status flags, bit mask 2^n.
// 4 least significant bits

$define VST_POTENZA_ATTIVA    1 // Power active, mask bit 0
$define VST_EXEC_COMANDO      2 // executing command, mask bit 1
$define VST_CARICA_INCORSO    4 // charge in progress, mask bit 2
$define VST_CARICO_PRESENTE   8 // load present, mask bit 3
```

The Battery box, indicate the amount of power consumed, not the remaining one. for example if the status is 100%, this mean the battery is empty, if the progress bar indicate 20%, this mean the remaining power is 80%. The value of the remaining gpower is shown in the *Battery capacity* progress bar in the tab *Vehicle informations [F3]*.

To emulate the Agv, first the Agv emulation should be active, state shown in tab Vehicles (Veicoli). Then in the vehicle tab the operating mode can be selected, and the status can be emulated. The Agv should be in automatic and power is enabled in order to move the Agv. For example, if we set the flag *Load present* to one, the agv behave depending on the script logic. If the load is a loading unit and there is a load in some

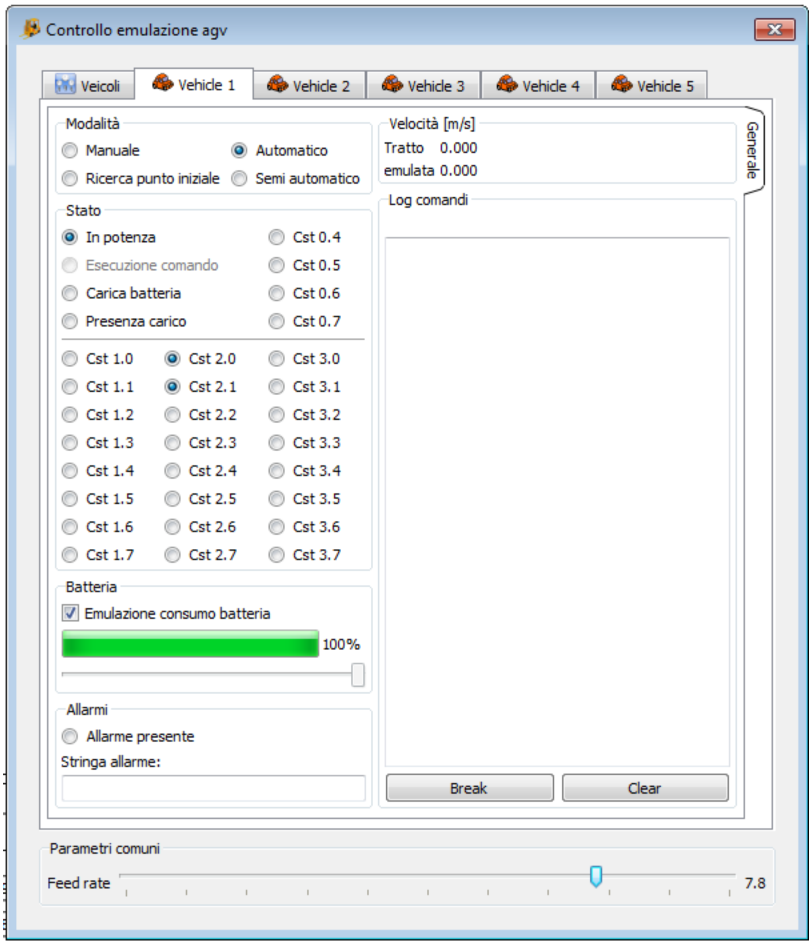


Figure 3.7: Emulation windows. We can see Agv status flags and other informations. The progress bar indicate the consumed power of the battery, not the remaining power, e.g. 100% is battery empty.

station to take out, the Agv will go to that station. Or for example if the load is properly the final product the agv may transport it to some unloading station.

3.4.2 Point windows property

A user point can be viewed as rectangle, where the dimensions are set in AgvConfigurator. A CBat (Battery point) is shown as a battery icon and . A double click on a user point or battery point a window is opened, see fig.3.8.

In the tab Storage informations, fig.3.8a, changing the type we can see the description associated to is, e.g. Type 1 is an empty trolley. The spin box (numeric updown control) is used to show only the type, the type is a combination of the checkboxes.

Properties assigned by the function *AddIntProperty()*, are shown in the tab Properties fig.3.8b.

3.5 AGV script executing

AGV manager can be compared to a plc (hardware and firmware) and the script to a plc program. The firmware is the same in all plant (beside updates and new functionality) and the script change from plant to another.

AGV scripts are written in Xscript language. Xscript have some OOP properties (creating classes and objects), some event handling (mouse move event) and callback functions.

3.5.1 Fundamental concepts

Callback functions are called automatically by AgvManager. A list of callback functions can be found in the documentation *x-script interface, Modules, Estensione x-script per AgvManager, Functions called by AgvManager (callbacks).*

For example the callback function *OnApplicationStart() : bool* is called once, at the first execution of the script, and the function *OnApplicationStop() : bool* is called when the script execution is stopped.

An example of mouse event handling is the function *onAgvDroppedToPoint (uint uagv, uint upointid, uint orientation)*. When the agv is dragged and dropped to a point, agv manager call automatically the function onAgvDroppedToPoint() and the code implemented will be executed. As input parameters, the agv index (agv 1 have index 0), destination point and orientation are passed.

In the following section we will se when other callback function are called by AgvManager.

Some variable definitions (using #define keyword) can be found in the documentation *x-script interface, Modules, Estensione x-script per AgvManager, Funzioni per la gestione degli agv*. For example the AGV operative modes can be find with the prefix "MOD_ ", i.e. MOD_AUTOMATICO.

The following concepts have to be understood before proceeding: Mission, MACRO, MICRO and operations.

Let's say a vehicle have to go from P_1 to P_2. This can be considered a mission. A Mission is started by calling *agvStartMission(agv id, missionCode, mission description)* and terminated by calling *agvStopMission(agv id).*

A mission can be composed from different MACROs. Let's say a MACRO is a macro operation that subdivide the mission. For example our mission can have 3 different MACROs. If the AGV is charging the battery, we have to stop charging (if the energy is enough to execute the whole mission), move to destination, communicate the end of the mission.

Using the 2 defined constants by AgvManager our mission is composed from : MAC_CHARGE_STOP, MAC_END and another macro that we can define using the $define keyword MAC_MOVE_TO_P. It is better to define our constants from 100 to avoid errors in the program logic. For example if the already defined constant MAC_END have value 10, and our constant MAC_MOVE_TO_WP have value 10, the compiler will not give errors and the agv will behave as is not expected.

AgvManager have in memory a list(array) of the MACROs to be executed. In the list are saved the agv number/id, MACRO code/id and other 4 parameters. When the function *agvaddmacro (uint uagv, uint ucode, int ipar1 = 0, int ipar2 = 0, int ipar3 = 0, int ipar4 = 0)* is called, the new MACRO is queued at the end of the list.

A MACRO is composed from MICROs. Let's say, low level micro instructions to be executed by the AGV. There are different types of MICRO, can be found in the constant defintions with prefix MIC_. For example MIC_MOVE is a MICRO that handle the motion instruction to the AGV.

A micro is registered (ask to be executed) by calling AgvRegisterSystemBloccante, agvRegisterSystemPassante, AgvRegisterOperation, etc.

An operation is a type of MICRO, a typical kind of operations are loading and unloading, and can be performed on user points. More about MICRO and operations later and the commands sent to the agv in order to execute orders from AgvManager. Remember that not all MIC instruction send commands to the agv.

3.5.2 Main loop execution

The following is a simplified explanation of the main loop of and AGV script, which is in execution behind the scene. A more complex scenario is shown in fig.3.9. When the script is executed the first time, the function OnApplicationStart() is called. In this function you can initialize some variables and set some parameters. After that AgvManager wait for events e.g. mouse events, or operating mode change. And continue to execute some other functions.

In the case we have more than one Agv, the execution of the functions is sequential. This means that the set of functions of Agv 1 are called first, then those of Agv 2, then Agv 3, etc. In other words, the flowchart in fig.3.9 and fig.3.10 are executed starting from the first Agv until the last in sequence, this flow is repeated always.

Let's see a simple case. The AGV is in automatic mode (MOD_AUTOMATIC), and there is no mission in progress. If the AGV is enabled, AgvManager call automatically the callback function onNextMission(), where the programmer have implemented a logic to register the next mission to be executed. When a mission is in progress, AgvManager wait

(wait doesn't mean stop script execution) till the end of the mission in order to call again onNextMission().

3.5.3 Mission execution

A mission is a set of MACROs. There is a list of MACROs, where the order of execution is assigned. A mission can be assigned typically inside the callback function onNextMission(), and started by calling AgvStartMission(). A mission can be also assigned in any other function. If the list of MACROs is not empty, the effective execution of the mission begin otherwise the old MICRO continue to execute until the end.

We take only one case, if the MACRO list is not empty, the function onExpand-Macro() is called by AgvManager. Then onExecuteMicro() is called. At the last call of onExecuteMicro() the paramater bLastCall is assigned to true.

Fig.3.10 show a flow chart about the mission execution. That is a single step of the mission. We have to imagine that AgvManager continue to call the flowchart like a plc, cyclically.

3.6 Drag and drop example

Let's consider a simple example. We have to write a script that react to mouse events from user. The vehicle have to move from one point to another.

First let's make a simple map, fig.3.11, with one line L_1 and two generic points P_{10} and P_{20}, the script will work on any map. After the configuration with AgvConfigurator, we open AgvManager in order to write the script and simulate. Notice that, after any modification of the script, AgvManager must be closed then opened.

A simple program like this, should have at least the following callback functions:

1. OnApplicationStart() : bool
2. OnAgvDroppedToPoint(uint uAgv, uint uUser)
3. OnExpandMacro(uint uAgv, uint uMission, uint iMacroCode, int iPar1, int iPar2, int iPar3, int) : bool
4. OnExecuteMicro(uint uAgv, bool bLastCall, int iMicroCode, int iPar0, int iPar1, int iPar2, int, int, int userId, int iMission, int) : bool
5. OnAbortMission(uint uAgv)

For simplicity we don't implement our own functions. Attached to this document will be provided the example we discuss here, and an equivalent example where other functions and files were added in order to keep the projects modular. The modular example is organized as follow: 3 files, 5 callback functions, 2 user-defined functions and some variable and constant definitions. A file called main.xs contain the inclusion of the other 2 files. A file called agvEventFunctions.xs where callback functions are implemented. A file called common.xs where common functions and variables definitions are implemented. This strucutre is meant to be a template for future projects, as many functions can be reused. Of course other files and functions can be implemented. The structure of any project should be modular, portable and reusable.

The single file example have 5 callback functions and some constant definitions. By convention, constants are written using capital letters. We will discuss the functions in order of execution. The function *onAbortMission()* is called when a mission is aborted, it will be discussed at the end.

onApplicationStart()

The implementation of this function is shown in listing 3.1. As we say before, this is the first function called by agvManager. first we create a variable *mpar* of type *XMapParms*. This is a structure that will contain informations about the vehicle. By the function *agvGetMapParams(xmapparams&)* we read the existing data from AgvManager and we initialize the variable mpar with those data. We change some parameter using the dot operator of the structure, for example we set the dimension of the vehicle i.e. *mpar.setSymmetricalVehicleDimension(length, width)*. After we apply the changes to AgvManager using the function *AgvSetMapParams(@mpar)*.

When the execution of this fucntion is done, AgvManager wait for some event. Let's suppose, the user drag the agv, in this case the event function *OnAgvDroppedToPoint* is called.

```
; ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
; Function called at program startup
; Operations to initialize the plant.
; ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
code OnApplicationStart() : bool
  SetVersioneManager(nvmake(MAJOR_VERSION, MINOR_VERSION, BUILD_VERSION
    ))

  XMapParams mpar
  ;
  ; Very important: before changing some parameters, load defaults!!!
```

```
  ;
  AgvGetMapParams(@mpar)
  ; Set vehicle dimensions: length, width
  mpar.setSymmetricalVehicleDimension(2300, 900)
  ;
  ; Parameters to calculate length of paths
  ;
  mpar.dHandicapForRotation = 8000       ; Distance added when using a
   cross for rotation
  mpar.dHandicapForCurve = 4000          ; Distance added when using a
   curve
  mpar.dDistanzaDaIncrocioOkFermata = 0   ; Minimum distance from cross
    to allow agv stop executing a movement
  ;
  ; Parameters to modify path assignment
  ;
  mpar.bOkInversioneSuIncrocio = false    ; True to permit inversion on
    a cross point
  mpar.bNoFermataSuIncrocio = true        ; True does forbid to stop on a
    cross point
  mpar.bNoMovSuTrattiPrenotati = false    ; True to forbid movement
   that ends on a point reserved for movement by another agv
  mpar.bPalletBloccaPercorso = true       ; Load unit (trolley) on path
   blocks the agv
; mpar.bDontMoveOnDestMove = true         ; Do not
  mpar.bNoPercorsoAgvDisab = false        ; Exclude paths occupied by agv
    that are not enabled
  mpar.bNoPercorsoAgvNoMis = false        ; Exclude paths occupied by agv
    that are not executing a mission
  ;
  ; Set parameters
  ;
  AgvSetMapParams(@mpar)

  AgvSetLunghezzaMove(12000)

  SetAccessLevelForOperation(DefQual_OpTrascinaAgvSuLinea, ACCESS_INST)

  return true
end
```

Listing 3.1: onApplicationStart implementation

OnAgvDroppedToPoint(uint uAgv, uint uPointId)

The call of this function is a response of mouse event. There are other mouse events like *onAgvDroppedToLine()*. In this function we set the behavior of the agv, what the agv have to do when it is dragged e.g. from P_{10} and dropped to point P_{20}. First let's put some requirements e.g. the agv should be in automatic mode, it should not be enabled, there is no mission in progress. If those conditions are meeted the agv can move from one point to another. The code to control such conditions is self-explainatory in listing.3.2.

This example will have only one mission, moving from one point to another. A mission should have at least one MACRO, every mission should have MAC_END. This MACRO inform the manager that it reach the end of the mission. There are some predefined constants for system used MACROs, they can be found in the documentation with the prefix MAC_. We can also define our own MACROs using the keyword Define. It is a good practice to use numbers from 100, every MACRO and mission should have a unique identifier.

Let's define our mission and a new MACRO:

```
; Mission null, ther is no mission
$define MIS_NULL              0
; Mission move to point
$define MIS_TO_POINT          14

; MACRO Movement to waypoint
$define MAC_MOVE_TO_WP        100
```

In this case the mission MIS_TO_POINT is composed from 2 MACROs. In order the *MACRO list* will have 2 elements:

1. MAC_MOVE_TO_WP
2. MAC_END

Before starting a new mission we check if there is a mission in progress. We call the function *AgvActualMissionCode(uint uAgvId)*, this function return the id of the mission in progress. If it return zero, it means there is no mission in progress. We have already define a constant MIS_NULL as zero. In the code we can write "*if(AgvActualMissionCode(uAgv)=0)*", but it is always more readable when using names instead of numbers, so instead of 0 we use MIS_NULL.

If there is no mission in progress, we can start the mission MIS_TO_POINT by calling the function *bool AgvStartMission(uint uAgvId, uint CodeMissione, string sMissioneDescription)*, this function return true if the mission is in progress.

Now we have to fill the agv MACRO list with our 2 MACROs, by calling the funntion *bool agvAddMacro(uint uAgv,uint uCodeMACRO, int ipar1=0,int ipar2=0, int iapr3=0, int ipar4=0)*. The iparX have 0 as default value.

The first MACRO is MAC_MOVE_TO_WP, this is a motion MACRO. So we have to build the path of the agv by calling the function AgvAddWaypoint(), this function take as parameters the agv id, the point id and direction and return an id of the point.

Then the MAC_MOVE_TO_WP can be add to the list, by calling agvAddMacro(), giving it as ipar1 the return value of the function AgvAddWaypoint() and as ipar2 a flag to concatenate the execution of the next MACRO. Then the macro MAC_END that end our mission is add to the macro's list.

```
  AgvStartMission(uAgv, MIS_TO_POINT, "Mission to point")
  ;
  uint wpidx
  uchar destOrientation = 'X'
  bool concatenateNext = true
  ;
  wpidx = AgvAddWaypoint(uAgv, uUser, destOrientation)
  AgvAddMacro(uAgv, MAC_MOVE_TO_WP, wpidx, concatenateNext)
  ;
  AgvAddMacro(uAgv, MAC_END, MIS_TO_POINT)
```

```
;
  ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
; Called when the user drags an agv (uAgv) to a point in map (uUser)
;
  ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
code OnAgvDroppedToPoint(uint uAgv, uint uUser)
  if (uAgv >= MAX_AGV)
    MessageBox("Invalid AGV number: " + (uAgv + 1))
    return
  end
  if (not AgvInAutomatico(uAgv))
    MessageBox("AGV " + (uAgv + 1) + " is not in automatic mode.")
    return
  end
```

```
  if (AgvAbilitato(uAgv))
    MessageBox("AGV " + (uAgv + 1) + " is enabled." + chr(10) + "Please
     disable it to give commands.")
    return
  end
  if (AgvActualMissionCode(uAgv) != MIS_NULL)
    MessageBox("AGV " + (uAgv + 1) + " is already executing a mission")
    return
  end
  ;
  AgvStartMission(uAgv, MIS_TO_POINT, "mission to point")
  ;
  uint wpidx
  uchar destOrientation = 'X'
  bool concatenateNext = true
  ;
  wpidx = AgvAddWaypoint(uAgv, uUser, destOrientation)
  AgvAddMacro(uAgv, MAC_MOVE_TO_WP, wpidx, concatenateNext)
  ;
  AgvAddMacro(uAgv, MAC_END, MIS_TO_POINT)
end
```

Listing 3.2: OnAgvDroppedToPoint implementation. This function as input have the AGV id and the destination point id. This is an evznt function it is called when the user drag and drop the vehicle to the desired point

OnExpandMacro()

As we mentioned before, when a mission begin the function OnExpandMacro() is called automatically by AgvManager. We already started a mission in the function OnAgvDroppedToPoint() and filled the MACRO list with 2 MACROs. So now we have to implement the function OnExpandMacro().

AgvManager executes the MACROs starting from the first one in the list. When it call the function OnExpandMacro(), give it the Agv id, mision id, MARCO code/id and the four parameters stored in the list. We can imagine every elements of the list, is composed from those fields. So in the implementation of this function we check the MACRO code to be executed. We can use the case statement or the if in order to select our logic.

The first MACRO is MAC_MOVE_TO_WP. Under the case MAC_MOVE_TO_WP we implement the instructions to AgvManager:

```
  case MAC_MOVE_TO_WP
    ; iPar1 = Waypoint id
    ; iPar2 = (bool) do concatenate next macro
```

```
    select (AgvMoveToWayPoint(uAgv, uMission, WpFl_RicalcolaPercorsi
  | WpFl_EliminaCompletato))
      case EsitoMov_MovimentoCompletato ; Completed movement
      case EsitoMov_RaggiuntoWaypoint   ; Waypoint reached
        if (iPar2)
          AgvComputeNextMacro(uAgv)
        endif
        return true
      default
        return false
    endselect
  return true
```

In this code the motion instruction is done by calling AgvMoveToWayPoint(), when this function return a value corresponding to MoveResult_WaypointReached, the next MACRO is expanded. The next MACRO in our example list is the END_MACRO.

When the return value of OnExpandMacro() is true, it mean the current macro execution is terminate, and on the next call the following macro will be executed.

As we say every MACRO consist of different MICROs. A MACRO that correspond to a motion have a MIC_MOVE. Here the MIC_MOVE is registered by the call of the movement function *AgvMoveToWayPoint()*.

The MAC_END register a MIC_SYSTEM micro type. When the MAC_END is expanded, it start or register a new micro. Simply this MACRO have only one MIC_SYSTEM micro type that is S_END.

This MICRO inform AgvManager that the mission is ended. In the case MAC_END the micro S_END is registered by calling *AgvRegisterSystemBloccante(uAgv, uMission, S_END)*, where the function *agvStopMission(uagv)* is called, as we will see in the function *onExecuteMicro()*.

As shown in fig.3.10, AgvManager continue to call onExpandMacro() and onExecuteMicro().

When the onExpandMacro() terminate the function onExcecuteMicro() is called.

In the tab vehicle informations[F3], under Agv commands we can se a list of missions, macros expansion and micro instructions, as well as information about them, fig.3.12, fig.3.13 and fig.3.14.

```
; ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
; Do the job assigned to the macro that has actually to be executed
;
; Return TRUE when all work has been done, and the macro is finished.
;
; Return FALSE when the work has not been finished: the function
; will be called again for this macro
;
; ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
code OnExpandMacro(uint uAgv, uint uMission, uint iMacroCode, int iPar1, int iPar2, int iPar3, int) : bool
  ;
  ; Macro expansion, depending by the macro code
  ;
  select (iMacroCode)
    case MAC_MOVE_TO_WP
      ; iPar1 = Waypoint id
      ; iPar2 = (bool) do concatenate next macro
      select (AgvMoveToWayPoint(uAgv, uMission, WpFl_RicalcolaPercorsi | WpFl_EliminaCompletato))
        case EsitoMov_MovimentoCompletato ; Completed movement
        case EsitoMov_RaggiuntoWaypoint   ; Waypoint reached
          if (iPar2)
            AgvComputeNextMacro(uAgv)
          endif
          return true
        default
          return false
      endselect
      return true

    case MAC_CHARGE_STOP
      AgvRegisterSystemBloccante(uAgv, uMission, S_CHARGE_STOP)
      AgvRegisterOperation(uAgv, uMission, O_CHARGE, O_CHARGE_STOP)
      AgvComputeNextMacro(uAgv)
      break

    case MAC_END
      SetAgvMessage(uAgv, "")
      AgvRegisterSystemBloccante(uAgv, uMission, S_END)
      break
```

```
    default
      qt_warning("Unknown macro: " + iMacroCode)
      break
    end
  return TRUE
end
```

Listing 3.3: OnExpandMacro

OnExecuteMicro()

MICROs are instructions to the vehicle. MICROs are stored in a list, one MACRO can register more than one MICRO fig.3.12.

For example a MICRO can be registered by calling agvRegisterSystemBloccante() or agvRegisterSystemPassante() for MIC_SYSTEM type or AgvRegisterOperation() for MIC_OPERATION type. See documentation for a more complete list of micro registration functions. These function have uAgv, uMission, MICROcode as input parameters.

There are different types of MICROs, that can be found in the documentation with prefix MIC_. Let's see MIC_SYSTEM to which the S_END belong, this type of MICRO doesn't send any instruction to the agv itself. For example S_END is need to end a mission, and is managed by AgvManager.

For example listing.3.4, register a 30 seconds waiting time.

```
  $define S_START_WAIT        100
  $define S_EXEC_WAIT         101
  AgvRegisterSystemBloccante(uAgv, uMission, S_START_WAIT, iPar1)
  AgvRegisterSystemBloccante(uAgv, uMission, S_EXEC_WAIT)
```

Listing 3.4: Wait time system micro

A MIC_MOVE type is related to instruction of motion sent to the agv. A MIC_OPERATION is an operation like loading and unloading.

There are 2 kinds of micros: blocking and non-blocking MICROs. The difference is that the blocking MICRO lock the execution of other micros till the end of the execution of itself or till the verification of a condition.

When expanding macros, the micro list is composed by calling the relative registration function. For example, in the function OnExpandMacro() under the MAC_END, we register a blocking system micro, S_END. In the function onExecuteMicro() under the case

MIC_SYSTEM and under the case S_END we call the function AgvStopMission(uAgv) in order to stop the mission. When a micro terminate the execution of the function onExecuteMicro() return true.

When the mission is stopped the macro list is eliminated, and the agv is ready to get another mission.

```
;
  ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
; Execution of the actions related to vehicle operations,
; and execution of the SYSTEM micro.
;
  ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
code OnExecuteMicro(uint uAgv, bool bLastCall, int iMicroCode, int
    iPar0, int iPar1, int iPar2, int, int, int userId, int iMission,
    int) : bool
  XVehicleInfo vInfo
  AgvGetVehicleInfo(uAgv, @vInfo)

  select (iMicroCode)

    case MIC_MOVE
    case MIC_CURVE
    case MIC_ROTATION
      return true

    case MIC_OPERATION

    case MIC_SYSTEM
      select (iPar0)
        case S_NULL
          ; Micro of that type are generated by AgvManager, I am not
    intereseted on it.
          break

        case S_END
          ; End of mission
          if (vInfo.uStatus & VST_EXEC_COMANDO)
            MultiMessageState(uAgv, "Agv " + (uAgv + 1) + ": wait for
    agv commands finished")
            return false
          endif
```

```
            MultiMessageState(uAgv, "Agv " + (uAgv + 1) + ": finished
    executing commands")
            AgvStopMission(uAgv)
            SetAgvMessage(uAgv, "")
            break
          default
            qt_warning("Unknown MIC_SYSTEM : " + iPar0 + " (mission = " +
     iMission + ", par1 = " + iPar1 + ")")
            break
        end
        break

      case MIC_PASSANTE
        select (iPar0)
          default
            qt_warning("Unknown MIC_PASSANTE : " + iPar0 + " (mission = "
     + iMission + ", par1 = " + iPar1 + ")")
            break
        end
        break

      case MIC_WAIT
        if (bLastCall)
          MessageState("Agv " + (uAgv + 1) + ": passthrough operation
    executed")
          return true
        end
        return false

      default
        qt_warning("Unknown micro: " + iMicroCode + " (mission = " +
    iMission + ", par0 = " + iPar0 + ", par1 = " + iPar1 + ")")
        break

  end
  return true
end
```

Listing 3.5: OnExecuteMicro

3.7 Summary

In automatic mode, if the Agv is not executing a mission, if it is enabled the callback function onNextMission() is called. If there is a mission in progress, even if the Agv is not enabled, continue to execute the mission till the end or till receiving an abort mission command, see fig.3.9.

For example, in the implementation of the function onNextMission() missions can be assigned to agv depending on the plant status, e.g. by calling a user defined function RegisterMission(). Th signature of the the function RegisterMission() can be defined as we wish.

```
//onNextMission()

// register mission depending on the plant logic
RegisterMission(uAgv, MIS\_LOAD\_FROM\_STATION, iPar1, iPar2)
```

Listing 3.6: onNextMission() missions are assigned

In the function RegisterMission(), depending on the mission we compile the macro list. For example if our mission is to go to load a product the macro list will composed in the following way:

```
// RegisterMission()

//Start mission with id uMissionCode
AgvStartMission(uAgv, uMissionCode, MissionDescription)

case MIS_LOAD_FROM_STATION
  //
  uint wpidx
  uchar destOrientation='X'
  bool concatenateNext=true
  wpidx = AgvAddWaypoint(uAgv, ID_LOAD_STATION, destOrientation)
  AgvAddMacro(uAgv, MAC_MOVE_TO_WP, wpidx, concatenateNext)

  // Wait for operator to load toilet
  AgvAddMacro(uAgv, MAC_WAIT_END_LOADING)

  // END of this mission
  AgvAddMacro(uAgv, MAC_END, uCode)
  break
```

Listing 3.7: RegisterMission() macro list is composed

When a mission is in progress, and the macro list is not empty, the callback function onExpandMacro() is called. Depending on the macro we compile a list of micro instructions. For example one of the macros was MAC_WAIT_END_LOADING:

```
//onExpandMacro()
case MAC_WAIT_END_LOADING
```

```
    AgvRegisterSystemBloccante(uAgv, uMission, S_START_WAIT, 30)
    AgvRegisterSystemBloccante(uAgv, uMission, S_EXEC_WAIT)
    AgvRegisterOperation(uAgv, uMission, O_WAIT_LOAD)
    break
```

Listing 3.8: onExpandMacro() micro list is composed

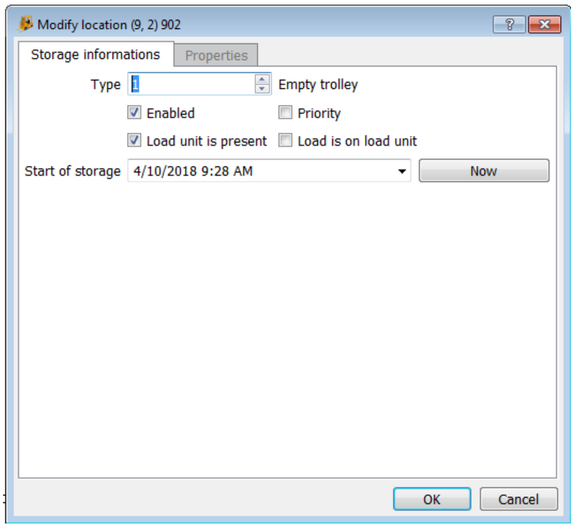
After the call of onExpandMacro() the callback function onExecuteMicro() is called, and depending on the micro we execute operation and instructions:

```
//onExecuteMicro()

case S_START_WAIT
  timerWait[uAgv] = timeoutS(iPar1)
  break

case S_EXEC_WAIT
  if (isTimeout(timerWait[uAgv]))
    return true
  else
    MultiMessageState(uAgv, "Agv " + (uAgv + 1) + " : wait " + int(
 secsToTimeout(timerWait[uAgv])) + "s")
    return false
  endif
  break
```

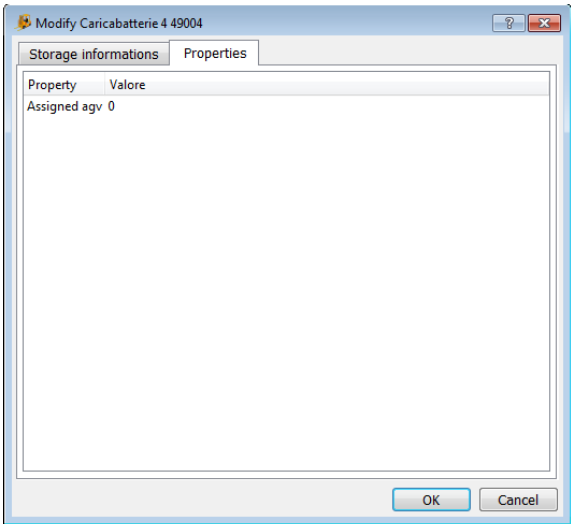
Listing 3.9: onExecuteMicro() micro are aexecuted

The state of mission execution is monitored cyclically. This mean that when a mission begin the functions onExpandMacro() and onExecuteMicro() are called repeatedly until the end of the mission, see fig. 3.10. The onExpandMacro() start executing the following macro in the list, when the previous returned true. The following micro is executed when onExecuteMicro() return true. the flag bLastCall is set to true by agvManager.

The main logic of AGVs is written in the function onNextMission(), where missions are assigned to AGV. When the logic is divided by missions, it is relatively easy to write the other 3 main functions : registerMission(), onExpandMacro() and onExecuteMicro(). Helper functions can be implemented to implement some useful logic.



(a) Storage information: Load information are shown, timestamp of loading, load type.



(b) Location properties

Figure 3.8: Location window: Storage information and properties

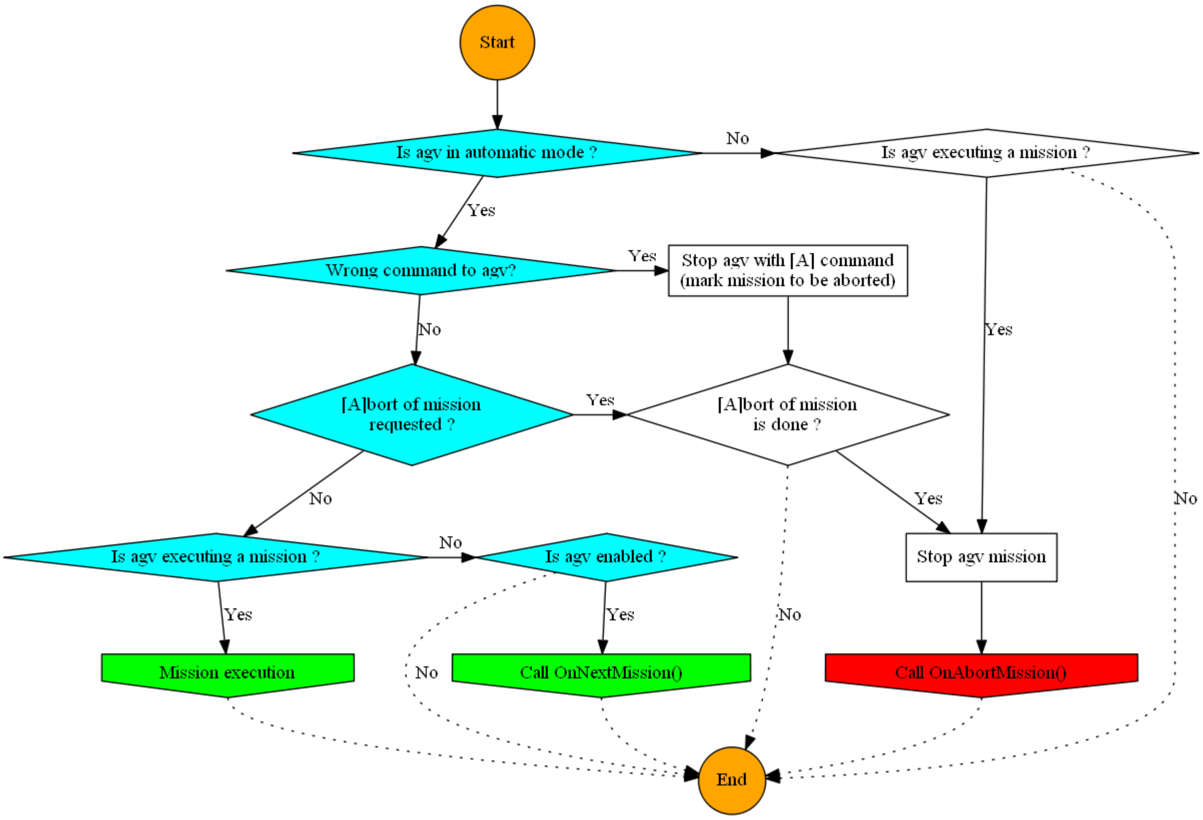


Figure 3.9: Main loop execution

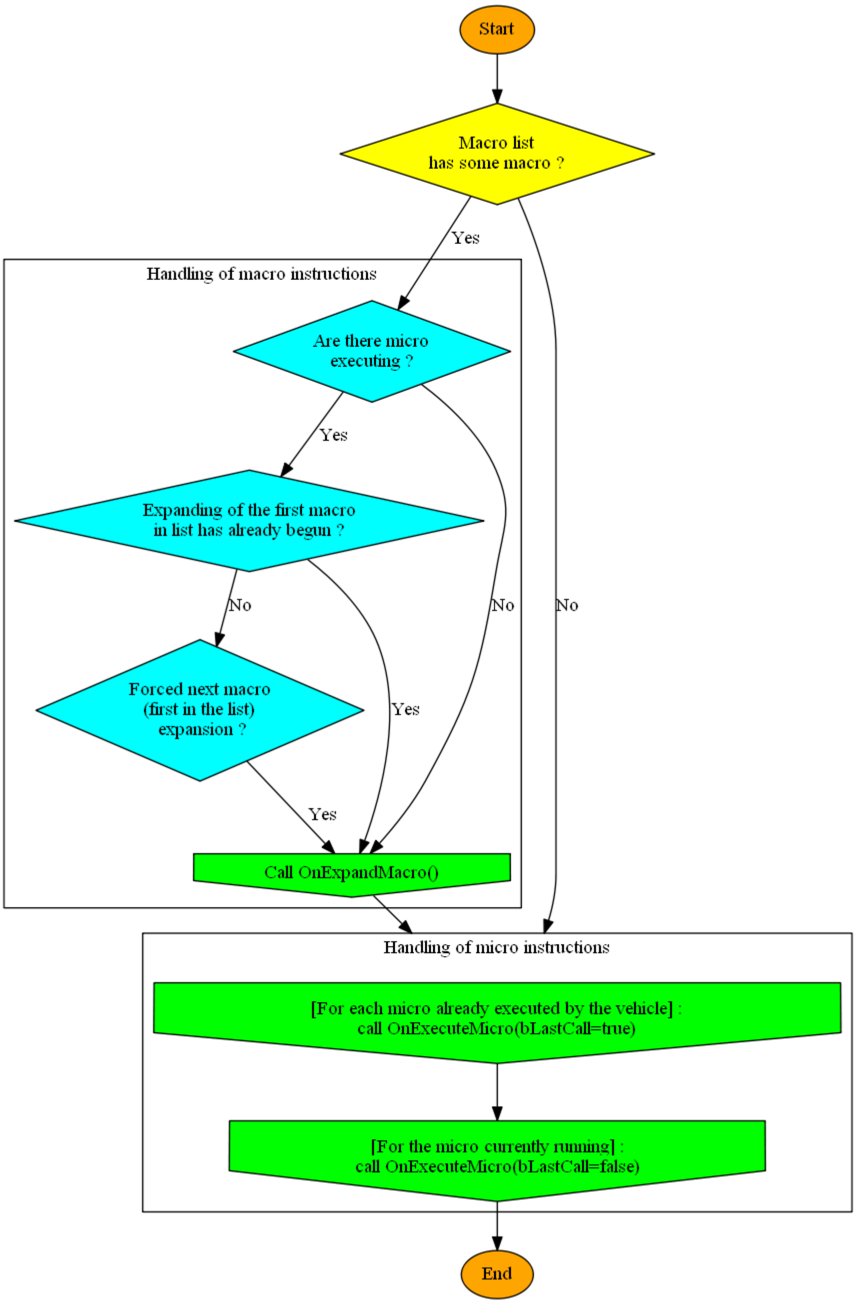


Figure 3.10: Main loop execution

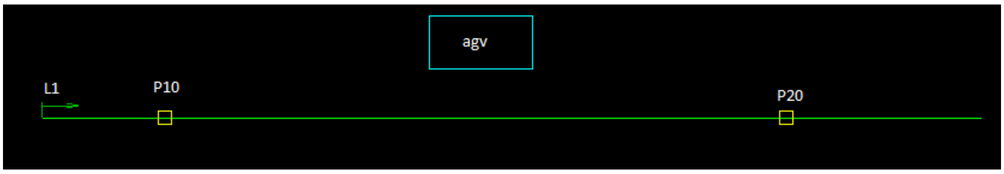


Figure 3.11: Agv simple map, for drag and drop example. One line and two generic points.

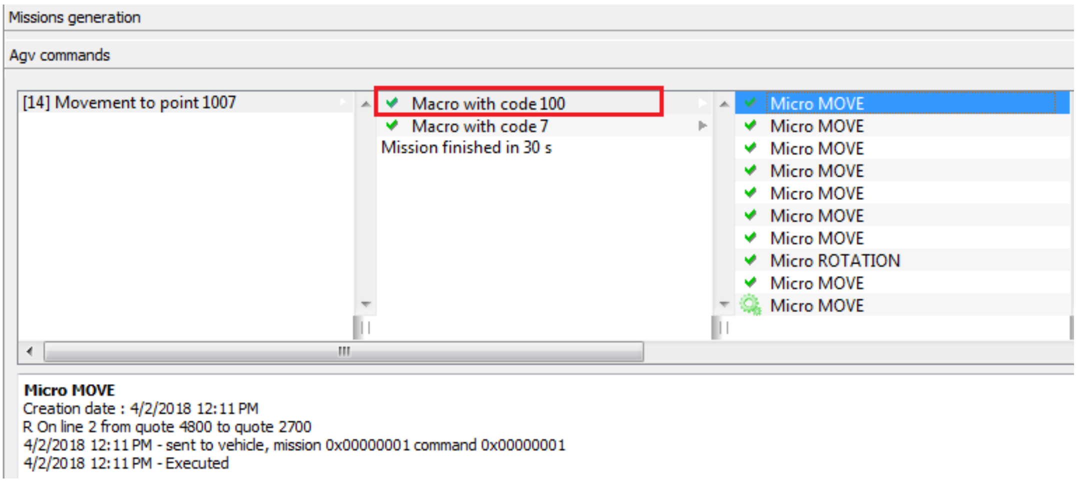


Figure 3.12: Movment to point 1007, Macro MAC_MOVE_TO_WP=100. As we can see, the macro consist of a list MICROs. Selecting a mission or a macro or a micro we can see informations about them.

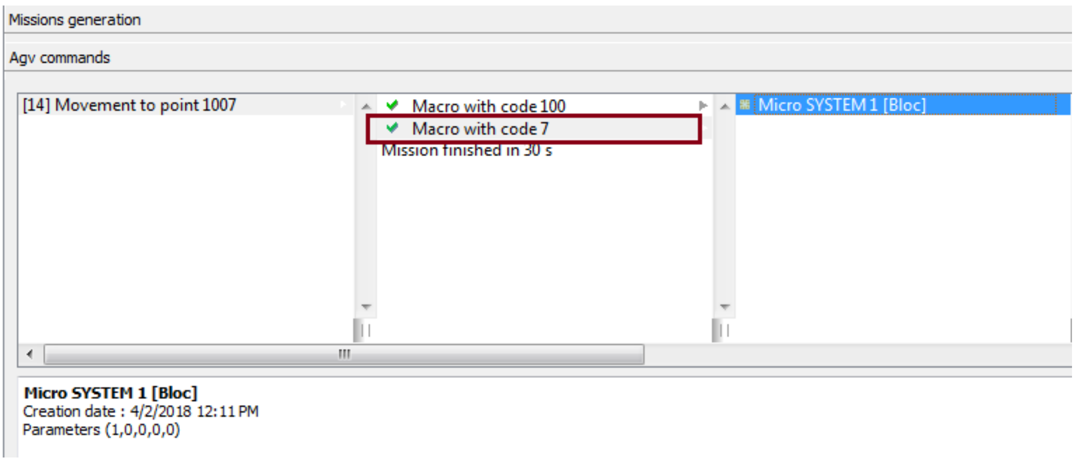


Figure 3.13: Movement to point 1007, Macro MAC_END=7. As we can see, the macro consist of on system micro that is S_END.

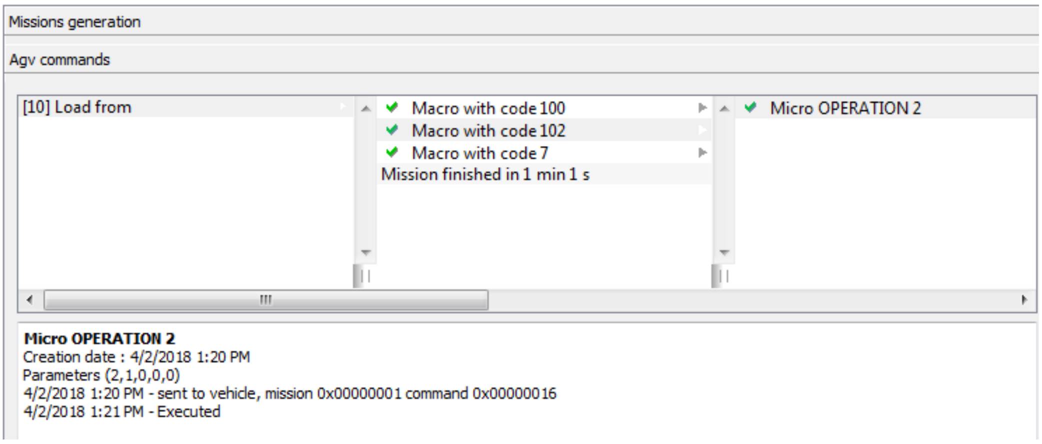


Figure 3.14: Mission load from a user point. The macro expansion shows 3 macros in the list. The MACRO 102, user defined, have only one micro of type operation that is O_LOAD, system defined. Later we will the commands sent to agv in order to execute operations.

4. More examples

In this chapter we will present some data structure of AgvManager and some examples on agv scripting. In this chapter we will show only piece of code necessary to explain the concepts. Complete examples are provided with this document. The expamples package is divided by folders, every folder contain the script files. Mainly every example at least have 3 files: main.xs, common.xs and agvEventFunctions.xs. We will indicate in which file and function every piece of code can be found.

In AgvManager documentation we can find functions and data structures divided by argument, it means functions to manage vehicles, maps, databases, etc. Refer to the official documentation in order to get a complete list of functions and data structures.

An Agv usually transport a loading unit (UDC, LU) e.g. pallet, trolley, etc. , or a loading unit with a load on it e.g. a pallet with some mechanical parts on it.

For the presence Loading unit we find the variable bPresenza or bPres. For the presense of a load on board of the Loading Unit (UDC) we find the variable bVasiPieni.

Data structures and constants definition can be found in Script editor - All functions.

4.1 Xscript Agv Data structures

In the documentation under the voice Estensione x-script per AgvManager » Funzioni per la gestione degli agv, we can find some functions and data structures to manage AGVs. Here will present some data structures and functions that can operate on them.

Note that AgvManager have internal data structures where to save informations about vehicles, maps, points, etc. When we need, for example to get information about agv number 4, we create a strucutre similar to the one AgvManager have and by calling a dedicated function we can get information on Agv 4.

4.1.1 XMapParams

This structures contains some fields to define the dimensions of an AGV and movement behavior. There are two functions that operate on this structure to get information from AgvManger and set information to it. For example, if we define a variable mPar as: XMapParams mPar, we can read parameter from AgvManager and store them into this structure by calling the function AgvGetMapParams(@mpar). If we need to modify some parameter we can we use the dot operator of the structure. To apply modification onto AgvManager we have to call the function AgvSetMapParams(@mpar), that transfer the data from the structure mPar to AgvManager.

Note the use of @ when passing the variable mPar to these 2 functions. The variable is passed by reference not by value.

Meaning of the structure fields??????????

```
;
;
//  Parametri definizione comportamento movimentazione veicoli
;
object XMapParams
  internal 0x02000093 setSymmetricalVehicleDimension(int length, int width, int diagonal=0)
  internal 0x02000094 setVehicleDimension(int length_front, int length_rear, int width_left, int width_right, int radius = 0)
  int iLunghVeicolo            // Larghezza veicolo (per anticollisione)
  int iLarghVeicolo            // Lunghezza veicolo (per anticollisione)
  int iDiagVeicolo             // Diagonale veicolo (per anticollisione, autocalcolata se == 0)
  int iVehicleLengthFront      // Lunghezza veicolo dal centro in avanti (per anticollisione)
  int iVehicleLengthRear       // Lunghezza veicolo dal centro all'indietro (per anticollisione)
  int iVehicleWidthLeft        // Larghezza veicolo dal centro verso sinistra (per anticollisione)
  int iVehicleWidthRight       // Larghezza veicolo dal centro verso destra (per anticollisione)
  int iVehicleRadius           // Raggio di massimo ingombro durante rotazione (per anticollisione)
  real dHandicapIncrocio       // Distanza aggiunta per uso incrocio (DEPRECATO)
```

```
    real dHandicapForRotation           // Distanza aggiunta per ogni rotazione
    real dHandicapForCurve              // Distanza aggiunta per ogni curva
    real dUseHandicap                   // Handicap per segmenti prenotati in senso contrario
    real dFattoreCurva                  // (Non usato, deprecato) Fattore moltiplicativo dell'ingombro in caso di curva
    real dAngMinCurvaOk                 // Angolo per cui il cambio di corridoio e' possibile con una rotazione anche se c'e' divieto di ingombro dei quadranti (cambio verso)
    real dHandicapIncontraDestMove      // Distanza aggiunta se si incontra un veicolo fermo. Se negativa non si passa proprio (ricerca di un percorso alternativo)
    real dHandicapMarciaIndietro        // Handicap moltiplicativo per tratti a marcia indietro
    real dDistanzaDaIncrocioOkFermata   // Distanza minima per fermata prima o dopo un incrocio in prenotazione movimento
    bool bOkInversioneSuIncrocio        // Ok inversione su incrocio
    bool bNoFermataSuIncrocio           // Vietato fermare su incrocio
    bool bPalletBloccaPercorso          // Non si passa su user di tipo 'C' occupato
    bool bNoMovSuTrattiPrenotati       // Non muovere gli agv su tratti prenotati da altri agv
    bool bNoPercorsoAgvNoMis           // Escludi dal percorso tratti su cui si trovano agv non in missione
    bool bNoPercorsoAgvDisab           // Escludi dal percorso tratti su cui si trovano agv disabilitati (e non in missione)
    bool bDontMoveOnDestMove           // Non muovere un agv se andrebbe a finire sulla destinazione di un altro agv
    int iAgvPosThreshold               // Soglia di posizione agv
endobject
```

Listing 4.1: XMapParams

4.1.2 XVehicleInfo

This data structure contain information about the vehicle, for example alarm status, mission in progress, operating mode, capacity of battery, etc. To get information from AgvManager about the vehicle we can call the function AgvGetVehicleInfo(uint agvId, xvehicleinfo& info), we pass to the function the index of the agv and an XVehicleInfo variable.

For example if we need information about Agv number 4, we create the structure XVehicleInfo vInfo, then we call AgvGetVehicleInfo(4, @vInfo). In this way, we can for example read the battery status vInfo.uBatteryCapacity. Note that after a while the Agv is working, this value will be different from the value AgvManager have, we have to call again the function AgvGetVehicleInfo(,) in order to update information.

The field uint uStatus, Vehicle Status Flag, is an 32 bit unsigned integer where information are saved in a binary way. There are defined some constants (flags) in order to decode information:

```
// Vehicle status flags, bit mask 2^n.
// 4 least significant bits

$define VST_POTENZA_ATTIVA    1 // Power active, mask bit 0
$define VST_EXEC_COMANDO      2 // executing command, mask bit 1
$define VST_CARICO_PRESENTE   8 // load present, mask bit 3
$define VST_CARICA_INCORSO    4 // charge in progress, mask bit 2
```

For example we need to know if the vehicle have a load on board, we can write: bLoadOnBoard = vInfo.uStatus & VST_CARICO_PRESENTE.

The first 4 bits (from 0 to 3), are reserved to system vehicle status (status communicated by the vehicle to AgvManager). The user can define its own flag status beginning from bit 4, depending on the state of the vehicle and the plant requirements.

```
//
//  Informazioni stato attuale veicolo
//
object XVehicleInfo
  uint uLineID              // Id. linea attuale agv
  int iPosition             // Posizione [mm] dell'agv sulla linea
   attuale
  int iAngle                // Angolo in gradi attuale dell'agv
  uint uMode                // Modalita' attuale veicolo (vedi etichette
   VM_***)
  uint uStatus              // Flag di stato veicolo (vedi etichette VST_
   ***)
  uint uAlarmStatus         // Flag di allarme veicolo
  uint uBatteryCapacity     // Capacita' batteria:
  // 0    = Batteria completamente carica
  // 1000 = Batteria completamente scarica
  float dBatteryPerc        // Percentuale carica batteria : 0.0  =
   completamente scarica, 100.0 = completamente carica
  uint uMission             // Id. missione attuale agv
  uint uCommand             // Id. comando attuale agv
  uint uDirV                // Direzione sul corridoio: uno tra [FRSD]
```

```
  uint uExtendedPalletId  // Identificativo informazioni estese pallet
   (se presenti)
  XLastMoveInfo lastMove  // Ultimo movimento registrato (.isValid
   indica validita', in piu' se non valido, .uLine == 0)
  XLastMoveInfo destMove  // Destinazione finale (.isValid indica
   validita', in piu' se non valido, .uLine == 0)
endobject
```

Listing 4.2: XVehicleInfo

4.1.3 XSiteInfo

A data structure where information about site can be stored. A site can be a user point or a battery point. By calling agvGetSiteInfo(int userPointId, XSiteInfo& sInfo) we can get the user point informations from AgvManager. The function have as parameter the id or code of the user point and a reference of a XSiteInfo variable. The function return true if the user point exist. With the function agvSetSiteInfo(int userPointId, XSiteInfo& sInfo) we can set the parameter of a user point in AgvManager.

For example the field bPresenza is a boolean variable that indicate if the user point contain a loading unit or not.

When executing a loading operation into the vehicle (from station to vehicle), by calling the function AgvExecLoad(agv,userPoint) the value of bPresenza is set to false and the vehicle status flag, uStatus, corresponding to VST_CARICO_PRESENTE is set to true.

When executing an unload operation (from vehicle to the station), by calling AgvExecUnload(agv, userPoint) the value of bPresenza to true. Note that these functions execute a logical load and unload. No commands are sent to agv. To let the agv execute a load or unload operations, agvRegisterOperation() must be called.

Some fields can be read and write (rw) from the script others are read only (ro).

bVasiPieni is a variable that indicate the presence of a load on the UDC (Loading Unit).

```
//
//  Informazioni associate a punto USER
//
object XSiteInfo
  bool bAttiva           // (rw)
  bool bPriorita         // (rw)
  bool bPresenza         // (rw) // UDT on board
  bool bVasiPieni        // (rw) // product on borad of UDT
  bool bInAllarme        // (rw)
```

```
  bool bVisibile            // (rw)
  uint uTipo                // (rw)
  uint uFlags               // (ro) // Vehicle flags. see UF_***
  real dStoreTime           // (ro) in giorni
  uint uLato                // (ro) [L (sinistra) | R (destra) | C (centro
    )]
  uint uExtendedPalletId // (ro) Identificativo informazioni estese
    pallet (se presenti)
endobject
```

Listing 4.3: XSiteInfo

By calling the function agvGetUserFlags(uint user), we get the user point flags (XSiteInfo.uFlags).

```
//
// Definizione codici User Flags
//
// Flags riservati ad AgvManager :
$define UF_MODIFIED              1
$define UF_NO_FREQ               2
$define UF_INUSE                 4
$define UF_PRE_INUSE             8
$define UF_PALLET_SU_PERCORSO    32
$define UF_MASK_FLAGS_AGVM       4095

// Flags impostabili da script ed usati da AgvManager
$define UF_ACCESSIBLE            0x00001000 // Passaggio attraverso
  user possibile (default vero)
$define UF_FORCE_STOP            0x00002000 // Obbligo di spezzare
  movimento
$define UF_NO_STOP               0x00004000 // Punto di sosta vietata
$define UF_NO_STOP_CROSS         0x00008000 // E' vietato fermare l'agv
   su questo incrocio
$define UF_FORCE_BREAK_CROSS     0x00010000 // Obbligo di spezzare
  movimento su incrocio
$define UF_BLINK_ICON            0x00020000 // Se sito in attesa di
  missione o riservato, icona blinka
$define UF_NO_INVERSIONE         0x00040000 // Vietato fare inversione
  su questo punto

// Flags impostabili da script e non usati da AgvManager
$define UF_RESERVED              0x00080000 // Prenotato da agv per
  missione (viene disegnato bollo rosso)
$define UF_MISS_OK               0x00100000 // Sito in attesa di
  missione (viene disegnato bollo verde)
```

```
$define UF_FLAG_XSCRIPT          0x01000000 // Primo flag utilizzabile
  liberamente da script

// Esempio d'uso :
// $define UF_MY_FLAG_1        shl(UF_FLAG_XSCRIPT,1)
// $define UF_MY_FLAG_2        shl(UF_FLAG_XSCRIPT,2)
```

Listing 4.4: User point flags

4.1.4 XListaSiti

The xListaSiti store a reference to a site (user o battery point). The operations done on elements of list are applied to sites in map. Imagine the list as a pointer to the sites in map.

```
//~~~~~~~~~~~~~~~~~~~~~~~~~~~~
//     Gestione lista siti
//~~~~~~~~~~~~~~~~~~~~~~~~~~~~

object XListaSiti
  uint pObj                    // INTERNAL POINTER - DO NOT TOUCH
  internal 0x02000600 Constructor()
  internal 0x02000601 Destructor()
  internal 0x02000602 IsEmpty() : bool     // Test se lista vuota
  internal 0x02000603 Count() : uint       // Ritorna numero siti in
   lista
  internal 0x02000604 Prepend(uint)      // Aggiunge sito in testa alla
   lista
  internal 0x02000604 AddHead(uint)      // DEPRECATED
  internal 0x02000605 Append(uint)       // Aggiunge sito in coda alla
   lista
  internal 0x02000605 AddTail(uint)      // DEPRECATED
  internal 0x02000606 Find(uint) : uint    // Torna posizione sito in
   lista (-1 se non trovato)
  internal 0x02000607 RemoveFirst() : uint  // Rimuove il primo sito
   dalla lista, e ne torna il valore
  internal 0x02000607 RemoveHead() : uint   // DEPRECATED
  internal 0x02000608 RemoveLast() : uint   // Rimuove l'ultimo sito
   dalla lista, e ne torna il valore
  internal 0x02000608 RemoveTail() : uint   // DEPRECATED
  internal 0x02000609 RemoveAt(uint) : uint // Rimuove il sito alla
   posizione specificata (ritorna l'indice del sito rimosso)
  internal 0x0200060A RemoveAll()        // Svuota la lista
  internal 0x0200060B At(uint) : uint      // Torna l'indice del sito
   alla posizione specificata
  internal 0x0200060C SetFlag(uint)      // Impostazione flag da settare
    per tutti i siti in lista
```

```
  internal 0x0200060D AllFlags() : uint   // Torna l'or binario dei
    flags di tutti i siti in lista
  internal 0x0200060E contains(uint) : bool // Test user presente in
    lista
endobject
```

Listing 4.5: XListaSiti

4.2 Some useful functions

We already see some callback funtions like onApplicationStart(), onNextMission(), onExpandMacro(), onExecuteMicro() and some utility functions like agvAddMacro(), agvAddWayPoint(), agvRegisterPassante(), agRegisterBloccante(), agvRegisterOperation(). There are a lot of functions provided by AgvManager. We will some of them in the examples. We will see also how we can create our own functions and objects.

4.2.1 Movement functions

In the documentation we can find some functions, e.g. agvMoveToWayPoint(), AgvRegisterMoveTo(), etc. to define the movement destination as well as the path agvAddWayPoint(), and some constants.

Constants related to this category of functions begin with MoveResult_ or EsitoMov_, some of these constants are self-explanatory, e.g. MoveResult_WaypointReached, MoveResult_CompletedMovement .

For example if we want to give the final destination without caring about the path we can call AgvRegisterMoveTo() in the callback function onExpandMacro() giving to it a input the destination point and agvManager build the path automatically. The path may be recalculated every time onExpandMacro() is called, depending on the state of the plant and other Agvs.

If we want to build the path we can use agvAddWayPoint() and agvMoveToWayPoint(). We register different macros as the way point. We can build the path by waypoints when we compile the macro list, in registerMission and registerMovement. Then the motion is executed in onExpandMacro() by calling agvMoveToWayPoint().

4.2.2 MICRO registration functions

The following functions register a micro operation or instruction:

1. agvRegisterSystemPassante(,,,,) MIC_SYSTEM, system micro instruction.
2. agvRegisterSystemBloccante(,,,,) MIC_SYSTEM, system micro instruction.

3. agvRegisterPassante(,,,,) [P] command, Pass-through operation.
4. agvReigsterOperation(,,,,) MIC_OPERATION [O] Operation to send to the vehicle. The syntax of the command is: [Occccmmmm,type,p1,p2,p3,p4].
5. agvRegisterMovingOperation(,,,,) MIC_MOVE [Q] Operation with movement.

6. agvRegisterWait(,,,,) [W] Wait condition operation.

To get a list of all micro type search in the documentation the prefix "MIC_". Other types of Micros are registerd directly by AgvManager like micro of type MIC_MOVE.

4.2.3 Points

- agvUserExists(uint uCode) : return true if a generic point, user point or cross exist.
- siteExists(uint uCode) : return true if the site (USER or CBat point) exists.
- agvGetSiteInfo(uint userId, xSiteInfo &sInfo): get information about USER point with id userId.
- SetSiteText(uint userId, string text) : set a text to shown on the user point on the map. e.g. SetSiteText(userId, "(" + row + ", " + col + ")").
- SetSiteName(uint userId, string text) : set the name of the site, visible in the tooltip

We can associate two different kind of properties to a point: int or string. Properties can be used by the script as we wish.

- SetIntProperty(uint, string, int)
- IntProperty(uint, string)
- addInProperty(,,,,)

```
AddIntProperty(i, PROP_ASSIGNED_AGV, "Assigned agv", ACCESS_INST
  , XSitePropertyFlg_volatile)

```

4.3 Creating functions and objects

Functions are useful to divided our logic and simplify the program. The keyword code is used to create functions. Use the keyword Forward, if you want to use the fucntion in another function that you implemented before it. It is like the prototype of the function in C language.

Objects are like classes in object oriented programming. Objects can be created by using object and endobjects. Classes have a constructor function, that is called when the class is instanciated, when the the object is created from the class.

4.4 Ex 01: Drag and drop example with loading and loading operations

In this example we will see how we can perform a drag and drop to a user point. A user point represent a working station, that could be machine or simply a position in a store. For example in an automatic store, a user point may represent the position where materials can be stoked or picked. A user point have a property called bPresenza that indicate the presence of material in the position designated by the user point or its absence.

OnAgvDroppedToPoint()

In the function OnAgvDroppedToPoint(), after the verification of requirements, we will register 3 missions depending on the case if the point is a user point or generic point, if the agv have a load or the user point have a load. In listing 4.6 the code and explanations are shown.

The code that verify the conditions: vehicle exist, in automatic, not enabled, no mission in progress is not shown here. I can be find in the complete example.

Listing 4.6 can be found in the file agvEventFucntions.xs in the callback function OnAgvDroppedToPoint().

```
// note comments in Xscript begin with ;

XSiteInfo sInfo // user point information strucutre
XVehicleInfo vInfo // vehicle strucutre information

// if user point and vehicle exist
if (AgvGetSiteInfo(uUser, @sInfo) and AgvGetVehicleInfo(uAgv, @vInfo)
 )

  bool loadOnAgv, loadOnUser
  // read the bit corresponding to lpad present on agv
  loadOnAgv = (vInfo.uStatus & VST_CARICO_PRESENTE)

  loadOnUser = sInfo.bPresenza

  //if both agv and user point have a load
  if (loadOnAgv && loadOnUser)
```

```
      MessageBox("Cannot move agv " + (uAgv + 1) + " to " + GetSiteName(uUser) + " : both have a trolley")
      return
    endif

    // if only agv have a load, the mission unload to user is registered
    if (loadOnAgv && not loadOnUser)
      // call to use defined function
      RegisterMission(uAgv, MIS_UNLOAD_ONLY, uUser)
      return
    endif

    //if only user point have load, the mission load to agv is registerd.
    if (loadOnUser && not loadOnAgv)
      RegisterMission(uAgv, MIS_LOAD_ONLY, uUser)
      return
    endif

  endif

  // register movement to point,
  //if there is no lad neither on agv neither on user point,
  //or if the point is a generic point
  RegisterMission(uAgv, MIS_TO_POINT, uUser)
```

Listing 4.6: Drag and drop to user point and generic point

When the user drag and drop the vehicle onto a point, the callback function OnAgvDroppedToPoint() is called, then the function RegisterMission() is called inside it as we can in the listing 4.6.

RegisterMission()

The function RegisterMission() is a user defined function, with the goal to assign missions, can be found in common.xs.

The keyword forward is used to define a prototype function, it tell the program that somewhere the function is implemented. if forward is not used, and we implement for example a functionA before a fucntionB, and functionA call fucntionB, the program will give error, because he expect that fucntionB is implemented before functionA.

The function have 4 input parameters: uAgv (agv code), uCode (mission id), iPar1 and iPar2. Where in this case in iPar1 is passed the point id.

Constants to identify missions and macros are defined as follow:

```
// Mission defition. Missions can begin from 0,
//because there are no missions already defined in AgvManger

// No mission in progress
$define MIS_NULL            0

$define MIS_LOAD_ONLY            10
$define MIS_UNLOAD_ONLY            11
$define MIS_TO_POINT            14

// MACRO definition, begin always from 100
// Movement to waypoint
$define MAC_MOVE_TO_WP            100
// Load from the point defined by par1
$define MAC_LOAD_TROLLEY            102
// Unload on the point defined by par1
$define MAC_UNLOAD_TROLLEY            103
```

In RegisterMission() we will start a new mission and fill the macro list with MACROs. We will use respectively agvStartMission() and agvAddMacro().

As you can notice, a mission is started by calling agvStartMission(uint agvId, uint missionId, string missionDescription). This function return true if a mission is in progress. We can define a new function that return a string value, to get the description of missions. After that we write a select case statement in order to fill the macro list depending on the mission code and to give movement instructions by calling the user defined function RegisterMovement().

For example, if our mission is MIS_LOAD_ONLY we register a movement to the user point by calling RegisterMovement(agvId,userPointId), where we will add the macro MAC_MOVE_TO_WP, then we add the 2 macros : MAC_LOAD_TROLLEY and MAC_END. So the macro list have 3 macros, table 4.1. This should be clear, the vehicle first move to the user point, once arrived, load the agv then finish executing the mission.

The same reasoning can be applied for other missions. Following the a part of the code:

```
// starting mission "uCode", with descrition "text"
if (not AgvStartMission(uAgv, uCode, text))
  return MIS_NULL
end
// user point info strutcture
XSiteInfo sInfo
```

uAgv	MAC code	iPar1	iPar2	iPar3	iPar4
1	MAC_MOVE_TO_WP	Waypoint id	concatenateNext		
1	MAC_LOAD_TROLLEY	User point code	bVasiPieni		
1	MAC_END	MIS_LOAD_ONLY			

Table 4.1: Macro list of the load mission, MIS_LOAD_ONLY. As you can see the paramters can assume different value types depending on the macro or micro

```

//Fill the macro list with the macro for the selected mission
// when we call registerMission(), we pass as iPar1 the user point
 index
select (uCode)
  // Loading agv mission
  case MIS_LOAD_ONLY
    if (not AgvGetSiteInfo(iPar1, @sInfo))
      // Strange error. Should not happen!!!
      AgvStopMission(uAgv)
      return MIS_NULL
    endif
    // iPar1 = point in store where toilet must be taken
    RegisterMovement(uAgv, iPar1)
    // Take the trolley with the toilet
    // Trolley with toilet
    AgvAddMacro(uAgv, MAC_LOAD_TROLLEY, iPar1, sInfo.bVasiPieni)
    // END of this mission
    AgvAddMacro(uAgv, MAC_END, uCode)
    break

  // unloading agv mission
  case MIS_UNLOAD_ONLY
    if (not AgvGetSiteInfo(iPar1, @sInfo))
      // Strange error. Should not happen!!!
      AgvStopMission(uAgv)
      return MIS_NULL
    endif
    // iPar1 = point in store where toilet must be taken
    RegisterMovement(uAgv, iPar1)

    // Leave the trolley with the toilet
    // Trolley with toilet
    AgvAddMacro(uAgv, MAC_UNLOAD_TROLLEY, iPar1, sInfo.bVasiPieni)
    // END of this mission
```

```
        AgvAddMacro(uAgv, MAC_END, uCode)
        break

    // movement to a point mission
    case MIS_TO_POINT
        //Move to selected point
        RegisterMovement(uAgv, iPar1)
        //END of this mission
        AgvAddMacro(uAgv, MAC_END, uCode)
        break

    // mission not defined
    default
        MessageBox("Mission not implemented: " + uCode)
        return MIS_NULL
  end
```

Listing 4.7: RegisterMission() code fragment

The function RegisterMovement() is self-explanatory.

```
code RegisterMovement(uint uAgv, uint userId, uchar destOrientation = '
    X',
        bool concatenateNext = true
        )
  uint wpidx
  //add waypoint, return an unique id of the added point.
  wpidx = AgvAddWaypoint(uAgv, userId, destOrientation)
  // add movement macro related to the point we get previously
  AgvAddMacro(uAgv, MAC_MOVE_TO_WP, wpidx, concatenateNext)
end
```

Listing 4.8: RegisterMovement() function

In this case mission are registered by calling the user defined function RegisterMission(). This function was called by the function OnAgvDroppedToPoint(). If we want to assign missions in another way, we can call the function RegisterMission() inside the callback function onNextMission() that is called when the agv is enabled.

Independently on how a mission is registered, when a mission is started the callback function onExpandMacro() is called in order to begin the execution of macros and micors.

onExpandMacro()

onExpandMacro() is called when there are MACROs in the macro list, check the flowchart in the official documentation and in the previous chapter, in the section mission execution.

To this callback function are passed the agv index, mission index, MACRO index, and 4 parameters. The agv index and mission index are passed from AgvManager to the function, that are related the the list to be expanded. Every mission have its own macro list. The parameters are read from the macro list.

```
code OnExpandMacro(uint uAgv, uint uMission, uint iMacroCode,
    int iPar1, int iPar2, int iPar3, int
    ) : bool

  select (iMacroCode)
    case MAC_MOVE_TO_WP
      // iPar1 = Waypoint id
      // iPar2 = (bool) do concatenate next macro
      select (AgvMoveToWayPoint(uAgv, uMission, WpFl_RicalcolaPercorsi
   | WpFl_EliminaCompletato))
        case MoveResult_CompletedMovement ; Completed movement
        case MoveResult_WaypointReached   ; Waypoint reached
          if (iPar2)
            AgvComputeNextMacro(uAgv)
          endif
          return true
        default
          return false
      endselect
      return true

    case MAC_LOAD_TROLLEY
      // par1 is the point
      // par2 is true if there is a toilet on the trolley
      // par3 is true it the trolley is ready to be taken out of store
      AgvRegisterOperation(uAgv, uMission, O_LOAD, iPar2, iPar3, 0, 0,
   iPar1)
      break

    case MAC_UNLOAD_TROLLEY
      // par1 is the point
      AgvRegisterOperation(uAgv, uMission, O_UNLOAD, 0, 0, 0, 0, iPar1)
      break

    case MAC_END
      SetAgvMessage(uAgv, "")
      AgvRegisterSystemBloccante(uAgv, uMission, S_END)
      break

    default
```

```
        qt_warning("Unknown macro: " + iMacroCode)
        break
    end
    return TRUE
end
```

Listing 4.9: onExpandMacro()

Simply the macro load register on operation of type O_LOAD, the unload macro register the O_UNLOAD operation and the end macro register the system macro S_END. These three micros are already defined by AgvManager. Search in the official documentation the prefixes O_ ad S_ to find a complete list Operations and System micro type.

The macro MAC_MOVE_TO_WP execute the movement command by calling AgvMoveToWayPoint(,,) and register a MIC_MOVE micro type. When the movement is completed or the waypoint is reached the function return true, that mean the expansion of the macro has finished.

After the expansion of macros, the micro are executed by calling the callback fucntion onExecuteMicro().

OnExecuteMicro()

We see how micros are registered when macros are expanded. Now we see how micros are executed. The MAC_LOAD_TROLLEY had registered an O_LOAD micro of type MIC_OPERATION. The MAC_UNLOAD_TROLLEY had registered an O_UNLOAD micro of type MIC_OPERATION and the macro MAC_END had registered an S_END of type MIC_SYSTEM.

```
case MIC_OPERATION
  select (iPar0)
    case O_LOAD
      if (bLastCall)
        MultiMessageState(uAgv, "Agv " + (uAgv + 1) + " : loaded from "
    + userId)
        SetAgvMessage(uAgv, "")
        // Agv has finished the load:
        // AgvExecLoad() puts the logical content of the user point
   identified by userId
        // on the agv, and removes from the user point.
        // NOTE: the operation was sent to the agv in OnExpandMacro()
        // expanding the macro MAC_LOAD_TROLLEY
        AgvExecLoad(uAgv, userId)
```

```
        return true
      else
        MultiMessageState(uAgv, "Agv " + (uAgv + 1) + " : loading from
   " + userId)
        SetAgvMessage(uAgv, "Loading")
        return false
      endif
      break

    case O_UNLOAD
      if (bLastCall)
        MultiMessageState(uAgv, "Agv " + (uAgv + 1) + " : unloaded to "
    + userId)
        SetAgvMessage(uAgv, "")
        AgvExecUnload(uAgv, userId)
        return true
      else
        MultiMessageState(uAgv, "Agv " + (uAgv + 1) + " : unloading to
   " + userId)
        SetAgvMessage(uAgv, "Unloading")
        return false
      endif
      break
    default
      qt_warning("Unknown MIC_OPERATION : " + iPar0 + " (mission = " +
   iMission + ", par1 = " + iPar1 + ")")
      break
  end
case MIC_SYSTEM
  select (iPar0)
    case S_NULL
      // Micro of that type are generated by AgvManager, I am not
   intereseted on it.
      break
    case S_END
      // End of mission
      if (vInfo.uStatus & VST_EXEC_COMANDO)
        MultiMessageState(uAgv, "Agv " + (uAgv + 1) + ": wait for agv
   commands finished")
        return false
      endif
      MultiMessageState(uAgv, "Agv " + (uAgv + 1) + ": finished
   executing commands")
      AgvStopMission(uAgv)
      SetAgvMessage(uAgv, "")
```

```
        break
end
```

In the case of O_LOAD and O_UNLOAD, AgvManager send associated commands to the vehicle. When the vehicle terminate the execution of the command associated to the micro, AgvManger call the callback function onExecuteMciro() with the parameter bLastCall is set to true. During the last call, when bLastCall=true we can perform also a logical load or unload by calling respectively AgvExecLoad() or AgvExecUnload().

The case of S_END, the function AgvStopMission(uAgv) is called in order to stop terminate the mission execution.

The MIC_MOVE are handled by AgvManager not by the script. So is not necessary to write the case of micro movements.

4.5 Overview on some functions

4.5.1 Access level

Sometime in a plant to a worker is permitted to do some job, to maintainer other jobs and so. In AgvManager are defined 5 different levels of users, that correspond to 5 different constants:

```
$define ACCESS_USER1  0
$define ACCESS_USER2  1
$define ACCESS_USER3  2
$define ACCESS_INST   3 // Installer
$define ACCESS_NO_OP  4
```

The actual level can be read by calling the function ActualAccessLevel().
SetAccessLevelForOperation(DefQual_OpTrascinaAgvSuLinea, ACCESS_INST).

4.5.2 onUpdateIO()

Drag and drop is useful to test vehicle. Normally a vehicle have to respond to some commands and react under some conditions that come from the plant. AgvManager can read input and output from a plc or a database. The callback function onUpdateIO(,,) is used to read input from a plc and write outputs to a plc.

IO can be defined in AgvConfigurator, in the tab PLC we define the communication protocol and the number of DWord (uint 32bit) to be exchanged in input and output. In the tab I/O description we can assign names to digital inputs and outputs. In AgvManager, in the tab Input/Output [F5] we can see the list of IO, read the value and force inputs and outputs.

The callback function onUpdateIO is called at the beginning of the main loop cycle. In this function we can read inputs by calling the fucntion agvGetInputXXXX and write outputs by calling agvSetOutputXXXX.

There are different get and set functions to read inputs and write outputs, it depend on what and how we read or write. For example, bool agvGetInput(uint offset) read the bit that have index "offset" and return a boolean value depending on the value of that bit. agvGetInputDWord(uint offset, uint& val) read the DWord at the index offset and write the value in val, note that val is passed to the function by reference.

Note that the first bit have $offset = 1$ not 0. It is convenient to define some constants that represent IO signals. For example it the signal Unloading done, e.g. a push button connected to input 7, i.e. byte 0 bit 7, we can define a constant like $define INP_UNLOADING_DONE 7, then call the function bool iUnloadDone= AgvGetInput(INP_UNLOADING_DONE). The same can be done for Outputs.

4.5.3 OnAgvStatusChange(): Agv status flag change

When the flag status of the vehicle (xVehicleInfo.uStatus) change value, the callback function OnAgvStatusChange() is called by AgvManager.

The fucntion SetAgvStatusDescription(uAgv, int stId, string desc). We can set the description of the bit with index stId. If we want e.g. to change the descrition of the status bit VST_CARICO_PRESENTE we have to write:

```
loadType = TYPE_EMPTY_TROLLEY
SetAgvStatusDescription(uAgv, -3, "<font color=" + colorName(
 AgvGetTYpeColor(TYPE_EMPTY_TROLLEY)) + ">Trolley on agv</font>")}
AgvSetAgvLoadInfo(uAgv, trolleyOnAgv, loadType, toiletOnTrolley)
```

In this example we change the description into "Trolley on agv", the string is HTML formatted string. This information is shown in the windows "Vehicle information".

The function AgvSetAgvLoadInfo() set information about the Loading Unit (UDC, Unita Di Carico) on the vehicle, e.g. AgvSetAgvLoadInfo(uAgv, bpresenza, loadType, bVasiPieni), bPresenza will be bPalletOnAgv, bVasiPieni will be bPalletFull.

4.5.4 OnAgvModeChange(): Agv Operating mode change

When the vehicle operating mode (xVehicleInfo.uMode) changed, AgvManager call the callback function OnAgvModeChange(uint uAgv, uint oldMode, uint newMode).

By calling the function bool AgvInAutomatico(uAgv) we get true if the Agv is in automatic mode, i.e. VM_AUTOMATICO, or in manual emergency mode, i.e. VM_MANU_EMERG.

Look for the prefix VM_ or MOD_ to get a list of operating modes, depending on the Agv navigation type.

4.5.5 Settings: XSettings

settings.ini file strucuture

4.5.6 Interaction with user: XForm

Qt creator

4.5.7 Semaphores

A semaphore can be only set to green by the script. A semaphore is set to red when all Agvs leave the area of the semaphore.

per quanto riguarda i semafori, come si fa ad associare l'agv alla richiesta? in AgvSetGreenSemaphore(uint , bool) il primo parametro e' il codice di startSemeforo, non c'e' il numero dell'agv.

Marco, 8:40 PM Una volta che il semaforo è verde lo è per tutti gli agv

8:52 PMAgvGetSemaphoreRequestMask(uint semaphoreStartId) : uint // Ritorna stato richiesta semaforo. Torna la maschera degli agv che stanno chiedendo il semaforocome fai a settare i bit della maschera?

Marco, 9:06 PMLi setta AgvManager quando degli agv stanno aspettando di passare per l'area del semaforoServe che il percorso di un agv incroci l'area del semaforo, e che l'agv sia nelle vicinanze del semaforo stesso: in pratica la maschera viene impostata quando il semaforo sta bloccando il movimento dell'agvOvviamente serve anche che venga chiamata una funzione di esecuzione movimentoViene anche impostata se ad esempio un operatore porta l'agv in manuale di emergenza dentro l'area di pertinenza del semaforo, o se all'avvio del software un agv si trova già dentro l'area.

```
;~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
; Gestione semafori
;~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
$define XSemaforo_nonesiste -1
$define XSemaforo_rosso 0
$define XSemaforo_verde 1
AgvGetSemaphoreRequestMask(uint semaphoreStartId) : uint       //
    Ritorna stato richiesta semaforo. Torna la maschera degli agv che
```

```
    stanno chiedendo il semaforo
AgvSetGreenSemaphore(uint semaphoreStartId, bool)         // Imposta
    conferma via libera semaforo con id semaphoreStartId
AgvGetSemaphoreColour(uint semaphoreStartId) : int         // Torna
    colore semaforo con id semaphoreStartId
```

Listing 4.10: Semaphores functions and constants

4.6 Ex 02: Storage example

In this example we will see how to handle a store with one agv. Let's suppose that use have a store with a matrix layout, one loading station and two unloading stations. The loading unit is a pallet. The agv go to the loading area with an empty pallet, a worker load the product manually on the pallet, once finish the Agv take the full pallet to the store. After a specific time the agv take out the pallets from the store to the unloading area following the FIFO (First In First Out) logic. The Agv leave the pallet in one unloading area, then go to the store to take another pallet or to the loading station to take some products. Keep in mind that the Agv need a pallet on board in order to load products, for this reason the Agv may take an empty pallet from the unloading area (if worker have already free the pallet from products) or turn back to the store to take an empty pallet then go to the loading area.

4.6.1 Missions

First of all we have to identify the missions in order to accomplish the requirements. It si relativley simple to do it. It is enough to write what the agv have to do in sequence, than figure out some special cases. For example a normal working flow is:

- the Agv have to take a product from the loading station
- then take it into the store
- then take out the product from the store
- then take it to the unloading area

this normal flow is composed by 4 missions. We say that the agv need a pallet on board in order to load products, so we need to take some pallet from somewhere. Let's say we can take empty pallets from the store or from the unloading area if the worker have already free the pallet. So we have other 2 missions.

- take empty pallet from store
- take empty pallet from unloading area.

Let's say the worker free the pallet in the unloading area, and we have to take out a full pallet from the store, before doing this we have to take out the empty pallet from the unloading area. Then take it to the store or to load products, notes that these 2 missions are already identified.

- take empty pallet out from the unloading area

Now suppose that we don't have anything to do and we have to wait to decide what to do, so we have a Null mission.

The agv use battery as power source, so a further mission could be: go to charging station. If the working time finish, at he end of the day we can decide to send the agv to some parking position: home position mission. We can figure out other mission, but for this example these missions are enough. Identified mission are summarized in the following listing:

```
// Missions
$define MIS_NULL                    0   // Nothing to do
$define MIS_LOAD_TOILET_FROM_STATION       1   // Go to loading station to take a trolley
$define MIS_PUT_TOILET_TO_STORE          2   //  Take the toilet to the store
$define MIS_LOAD_TOILET_FROM_STORE        3   // Take something out of store
$define MIS_LOAD_EMPTY_TROLLEY_FROM_STORE 4   // Take something out of store
$define MIS_TAKE_TOILET_TO_UNLOAD        5   // Take the toilt already on agv to unloading station
$define MIS_EMPTY_TROLLEY_FROM_UNLOAD     6   // Go take an empty trolley from unload area
$define MIS_PUT_EMPTY_TROLLEY_ON_STORE     7   // Agv has an empty trolley , put it on store

$define MIS_LOAD_ONLY               10
$define MIS_UNLOAD_ONLY               11
$define MIS_TO_BATTERY_CHARGE            12
$define MIS_TO_HOME                 13
$define MIS_TO_POINT                14
```

Listing 4.11: Agv Missions

The main logic of assigning missions will be implemented in the function onNextMission(). After assigning a mission a macro list have to be compiled, and it will be done in another function, called from onNextMission().

4.6.2 onNextMission()

Have a look on the main loop execution, fig.3.9 to get an idea about when the callback function is called or read the documentation. Now let's assign some mission to the agv.

First let's read the state of the AGV by calling AgvGetVehicleInfo(uAgv, @agvInfo) where uAgv is the Agv index and agvInfo is a XVehicleInfo. From the variable agvInfo we can get information about the battery capacity of the Agv, the status of the Agv, etc.

We have to check if the Agv have enough power to execute a mission, and if the Agv have a pallet (UDC) on board or not, if it have a pallet, it is empty or have some product? Let's define two flags in the agv flag status, agvInfo.uStatus. One to determine if the full pallet on the agv come from the store or from the loading area? For example $agvflg\_ProductGoingOutOfStore = TRUE$ then it is a pallet that come out from the store and should go to unloading area, otherwise if equal false, it come the loading area and have to go to the store. The other flag to determine if the pallet is empty or not, $agvflg\_ProductOnPallet$.

```
// user defined vehicle status flags
$define agvflg_ProductOnPallet       0x0100 // bit 8 in agvInfo.
  uStatus
$define agvflg_ProductGoingOutOfStore 0x0200 // bit 9 in agvInfo.
  uStatus
```

Then let's defined some boolean variables that will help in the decision and selection of missions:

```
bool mustGoToChargeBattery // no pwer, Agv must go the cahrg
bool trolleyOnAgv // Agv have pallet or loading unit, don't consider
  the product
bool toiletOnTrolley // Agv have a full pallet = Loading unit +
  product
bool takeOutToilet // Full pallet come out from store

// Unloading unit have empty trolley to take away
bool mustRemoveTrolleyFromUnload

mustGoToChargeBattery = (agvInfo.dBatteryPerc <= MIN_BATTERY)

trolleyOnAgv = (agvInfo.uStatus & VST_CARICO_PRESENTE)
toiletOnTrolley = trolleyOnAgv and (agvInfo.uStatus &
  agvflg_ProductOnPallet)
takeOutToilet = toiletOnTrolley and (agvInfo.uStatus &
  agvflg_ProductGoingOutOfStore)
```

Listing 4.12: Desision variables or plant status

Depending on the value of these variables we can assign mission to Agv. For example if the agv *have a full pallet on board and that pallet come out from the store, it should go* *to the unloading area.*

```
if (takeOutToilet)
  OnNextMissionDebugMessage(uAgv, "takeOutToilet=T : <font color=green>
   assign mission MIS_TAKE_TOILET_TO_UNLOAD</font>")
  return RegisterMission(uAgv, MIS_TAKE_TOILET_TO_UNLOAD)
endif
```

Listing 4.13: Mission to unloaing area

The function OnNextMissionDebugMessage() is used to show debugging messages in the vehicle information [F3] tab, in the box Mission generation.

If the Agv *have a full pallet and the pallet doesn't come out from the store, it come from the loading are*, the agv have to take the pallet to the store:

```
if (toiletOnTrolley)
  int storePosition
  // Find a position on the store where to put the trolley
  storePosition = store_hnd.positionForTakeInTrolley(uAgv, true)
  if (not SiteExists(storePosition))
    OnNextMissionDebugMessage(uAgv, "toiletOnTrolley=T : <font color=
   red>position in store not found</font>")
    return MIS_NULL
  endif
  OnNextMissionDebugMessage(uAgv, "toiletOnTrolley=T, storePosition=" +
     storePosition + " : <font color=green>assign mission
   MIS_PUT_TOILET_TO_STORE</font>")
  return RegisterMission(uAgv, MIS_PUT_TOILET_TO_STORE, storePosition)
endif
```

Listing 4.14: Mission take full pallet into store

If we look at the code again without the debugging info, it is simple. First we choose a position in the store where to go, then we assign the mission take trolley to the position chosen in the store.

```
if (toiletOnTrolley)
  int storePosition
  // Find a position on the store where to put the trolley
  storePosition = store_hnd.positionForTakeInTrolley(uAgv, true)
  //check if postion exist or storePosition <> (-1), register mission.
  return RegisterMission(uAgv, MIS_PUT_TOILET_TO_STORE, storePosition)
endif
```

Listing 4.15: Mission take full trolley to a postion in the store

As we see the logic to assign Missions should not be complicated. Once missions are identified, it is enough to assign them to Agv without caring about the details of a mission. To do so, we call a user defined function RegisterMission(uAgv, uMission, iPar1, iPar2), or any number of parameters we need. The detail about mission step (MACROs) are implemented in the function registerMission.

Until now we assign 2 missions MIS_TAKE_TOILET_TO_UNLOAD and MIS_PUT_TOILET_TO_STORE, depending on the conditions *takeOutToilet* and *toiletOnTrolley*.

Pay attention to the sequence of implementing the functions or to the conditions. It is better to write if (toiletOnTrolley and not takeOutToilet) then writing if (toiletOnTrolley), in this way we don't care about the sequence of writing the conditions.

4.6.3 Macros

Once missions are defined, we have to defined MACROs. First take a look at macros defined by AgvManager.

```
// MACRO code definition
$define MAC_NULL                0
$define MAC_MOVE_TO_USER        1
$define MAC_MOVE_TO_XY          2
$define MAC_CHARGE_BATT         3
$define MAC_CHARGE_STOP         4
$define MAC_LOAD                5
$define MAC_UNLOAD              6
$define MAC_END                 7
$define MAC_MOVE_AND_LOAD       8
$define MAC_MOVE_AND_UNLOAD     9
```

Listing 4.16: MACRO defined in AgvManager

If other macros are needed we can define also ours.

```
  // Movement to waypoint
  $define MAC_MOVE_TO_WP            100
  // Wait for the amount of seconds specified in par1
  $define MAC_WAIT_S              101
  // Load a trolley from the point defined by par1
  // par2 is true if there is a toilet on the trolley
  $define MAC_LOAD_TROLLEY          102
  // Unload a trolley on the point defined by par1
  $define MAC_UNLOAD_TROLLEY          103

  // Wait for the operator to load toilet on agv
  $define MAC_WAIT_TOILET           200
```

```
// Decide the unloading point where the toilet will be unloaded
$define MAC_TAKE_TOILET_TO_UNLOAD     201
// Decide where to take an emty trolley: whether to load station or
  to store
$define MAC_DECIDE_EMPTY_TROLLEY_DEST  202
```

Listing 4.17: MACRO defined by user

To define Macros, we go back to the list of missions, and write the detail of the missions. Once again without too much detail, becuase the instructions and operations sent to and received from agv are handled by MICROs. For our example we can assign the following macros to each mission. Usually this is done in register mission, or a fucntion called from onNextMission().

- MIS_LOAD_TOILET_FROM_STATION 1
  - MAC_MOVE_TO_WP , move to station user point
  - MAC_WAIT_TOILET , wait loading toilet, wait for signal load ok
  - MAC_END
- MIS_PUT_TOILET_TO_STORE 2
  - MAC_MOVE_TO_WP , move to the store position
  - MAC_UNLOAD_TROLLEY , unload trolley
  - MAC_MOVE_TO_WP , go out from store
  - MAC_END , end macro
- MIS_LOAD_TOILET_FROM_STORE 3
  - MAC_MOVE_TO_WP
  - MAC_LOAD_TROLLEY
  - MAC_MOVE_TO_WP
  - MAC_END
- MIS_LOAD_EMPTY_TROLLEY_FROM_STORE 4
  - MAC_MOVE_TO_WP
  - MAC_LOAD_TROLLEY
  - MAC_MOVE_TO_WP
  - MAC_END
- MIS_TAKE_TOILET_TO_UNLOAD 5
  -
  - MAC_MOVE_TO_WP
  - MAC_TAKE_TOILET_TO_UNLOAD
  -
- MIS_EMPTY_TROLLEY_FROM_UNLOAD 6
  - MAC_MOVE_TO_WP

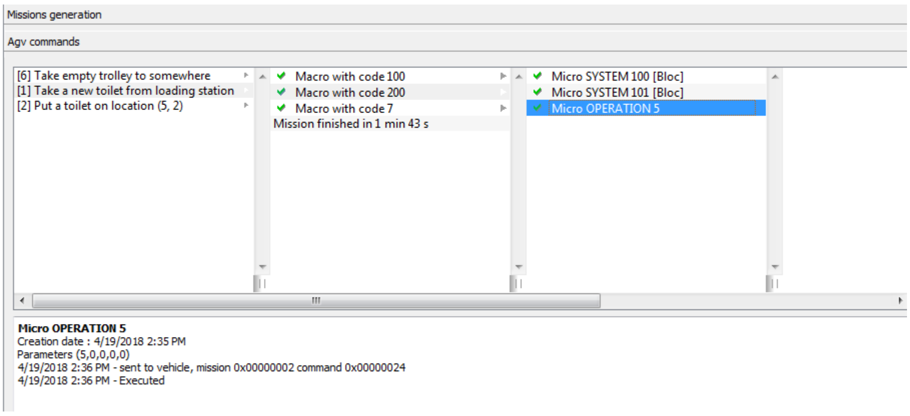


Figure 4.1: Macro expansion and micro details

  - MAC_LOAD_TROLLEY
  - MAC_MOVE_TO_WP
  - MAC_DECIDE_EMPTY_TROLLEY_DEST
- MIS_PUT_EMPTY_TROLLEY_ON_STORE 7
  - MAC_MOVE_TO_WP , move to the store position
  - MAC_UNLOAD_TROLLEY , unload trolley
  - MAC_MOVE_TO_WP , go out from store
  - MAC_END , end macro

Once MACROs are assigned to missions, we have to assign MICROs to MACROs, this may be done in onExpandMacro(). Remember that when onExpandMacro() return true, mean the execution of the current macro is concluded, and the next macro in the list will be expanded (executed) on the next call of onExpandMacro(), of course if the current macro is not the last one in the list.

We can also end a mission and begin another one from onExpandMacro(). We don't have to do it always in onNextMission(). But keep in mind that the program should be linear and simple. Avoid spaghetti code when is possible.

When a macro is expanded we can see the result in vehicle information[F3], fig.4.1.

For example to make a loading operation, we have to call AgvRegisterOperation(), as in listing 4.18.

```
case MAC_LOAD_TROLLEY
  // par1 is the point
  // par2 is true if there is a toilet on the trolley
  // par3 is true it the trolley is ready to be taken out of store
  AgvRegisterOperation(uAgv, uMission, O_LOAD, iPar2, iPar3, 0, 0,
    iPar1)
  break
```

Listing 4.18: Loading MACRO

The call of AgvRegisterOperation in 4.18, register a MICRO of type MIC_OPERATION.

4.6.4 Micros and Operations

Micros are low level set of instructions. The following listing.4.19 show the different categories of micro instructions or operations defined by AgvManager.

```
// Definizione codici micro
$define MIC_NULL                0
$define MIC_MOVE                1 // M command, agvregisterMove****
$define MIC_CURVE               2 // M command
$define MIC_ROTATION            4 // M command
$define MIC_OPERATION           5 // O command, agvregisterOperation()
$define MIC_SYSTEM              6 //   command are not sent to vehicle,
    agvregistersystembloccante(), agvregistersystempassante()
$define MIC_PASSANTE            7 // P command, agvregisterPassante()
$define MIC_WAIT                8 // W command, agvregisterWait()
$define MIC_MOVING_OPERATION    9 // Q command,
    agvregisterMovingOperation()
```

Listing 4.19: Different catergory of MIC defined in AgvManager

The following are MICROs defined by AgvManger.

```
// Definizione codici operazioni
$define O_LOAD          2
$define O_UNLOAD        3
$define O_CHARGE        4
$define O_CHARGE_START  1
$define O_CHARGE_STOP   2

// Definizione codici micro System
$define S_NULL          0 // Serve (ad esempio) a spezzare le MIC_MOVE
$define S_END           1
$define S_CHARGE_WAIT   3
$define S_CHARGE_START  4
$define S_CHARGE_STOP   5
$define S_CONCAT_MACRO  8 // Concatena immediatamente la macro
    successiva
```

Listing 4.20: MICRO and OPERAIONS defined by AgvManager

We can define are own Micros and operations. Try to follow the naming style of AgvManager. Begin with the prefix O_ for Operation category, with S_ for System category.

```
//   Micro SYSTEM
$define S_START_WAIT     100
$define S_EXEC_WAIT      101

//   Micro OPERATION
// Wait toilet on agv
$define O_WAIT_TOILET    5
```

Listing 4.21: MICRO and OPERAIONS defined by user

Micros form category MIC_OPERATION, MIC_SYSTEM, MIC_PASSANTE, MIC_WAIT are assigned in onExpandMacro(), using one of the following functions:

```
  // Blocking operation
  AgvRegisterOperation()
  // passthrough operation
  AgvRegisterPassante()
  // Operation during motion
  AgvRegisterMovingOperation()

  //
  AgvRegisterWait()
  AgvRegisterSystemPassante()
  AgvRegisterSystemBloccante()
```

Micros that belong to MIC_MOVE, MIC_CURVE, MIC_ROTATION are assigned by AgvMoveTo****() functions.

Micro execution is done in onExecuteMicro(), for example:

```
case MIC_SYSTEM
  case S_END
    ; End of mission
    AgvStopMission(uAgv)
    SetAgvMessage(uAgv, "")
    break

  case S_START_WAIT
  // start timer. Not locking micro
    timerWait[uAgv] = timeoutS(iPar1)
    break

  case S_EXEC_WAIT
  // wait a timer to finish counting. locking micro
    if (isTimeout(timerWait[uAgv]))
```

```
      return true
    else
      MultiMessageState(uAgv, "Agv " + (uAgv + 1) + " : wait " + int(
   secsToTimeout(timerWait[uAgv])) + "s")
    return false
    endif
    break

  case S_WAIT_INPUT
  // wait a signal from plc. locking micro
    if ( AgvGetInput(INP_LOAD_TERMITAED) ==false )
      return true
    else
      return false
    endif
```

Keep in mind that when a micro terminate, onExecuteMicro() should return true. For example, if we are waiting for a signal to be false, and the signal is true, onExecuteMicro() return false, in this way the next micro will be the current one. When the signal become false, onExecuteMicro() return true and the execution of the current micro terminate.

When bLastCall will be set to true? at the next execution or immediately, and the effective termination will be at the next call?

```
case O_LOAD
  if (bLastCall)
    MultiMessageState(uAgv, "Agv " + (uAgv + 1) + " : loaded from " +
   userId)
    SetAgvMessage(uAgv, "")
    // Agv has finished the load:
    // AgvExecLoad() puts the logical content of the user point
   identified by userId
    // on the agv, and removes from the user point.
    // NOTE: the operation was sent to the agv in OnExpandMacro()
    // expanding the macro MAC_LOAD_TROLLEY
    AgvExecLoad(uAgv, userId)
    // Position is no more reserved to agv
    store_hnd.unassignAgvToLocation(uAgv, userId)
    return true
  else
    MultiMessageState(uAgv, "Agv " + (uAgv + 1) + " : loading from " +
   userId)
    SetAgvMessage(uAgv, "Loading")
    return false
```

Figure 4.2: Commands insertion

```
endif
break
```

Listing 4.22: Loading MIC OPERATION

For example if we register a micro from the category Operation, AgvManager will send some command to the vehicle. When the vehicle answer with operation concluded, AgvManager will set bLastCall to true, in this way we can terminate the micro execution.

From AgvManager we can send command to agv from the interpreter box. For example the operation command structure is: [Occccmmmm,type,p1,p2,p3,p4]. For example [O00010003,1,0,0,0,0], fig.4.2, we send to Agv an operation command [O], with operation number 1 and mission number 3.

Details about mission, macro and micro execution can be seen in the tab vehicle informations[F3].

4.6.5 Store handling

In a matrix store, or stack, products can be taken out following the logic of First in First out (FIFO) or Last in First out(LIFO), etc.

We can define some objects to handle the store, keep in memory the products in the store and track them, and also some algorithm to take out or take in products.

II

Motion control

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5. Overview

Robox controller RP1, is a motion control ..... parts, description,......

RDE need Microsoft c++ redistributable 2010 and 2015 x86

In this part we will see Robox IDE for motion control called RDE, RTE that is the real-time operating system of Robox and the commissioning of AGV using its already existing software written in R3 and Object block (C language).

5.1 Components

RP-1, RTE, RDE, ...

5.2 Multitasking

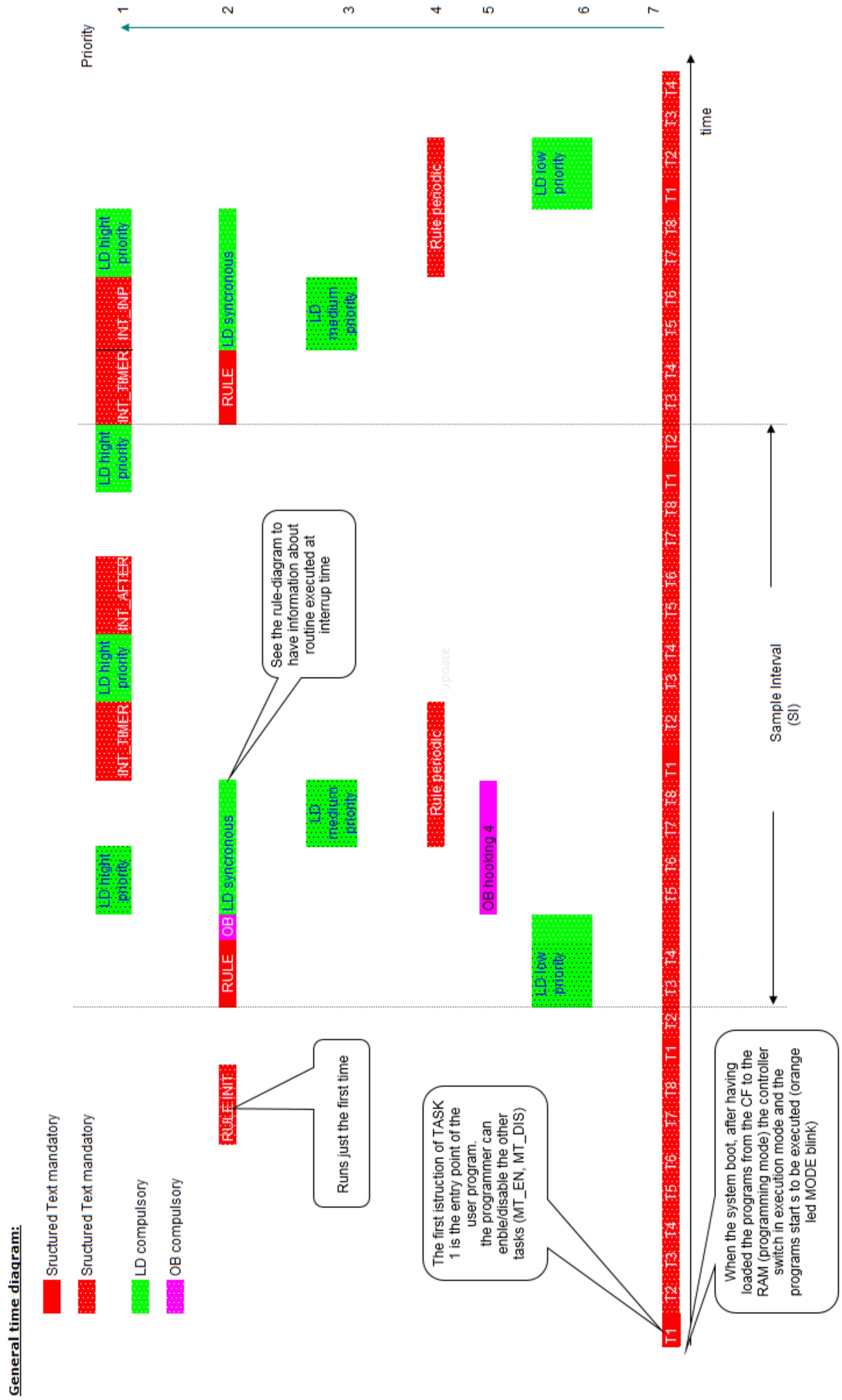
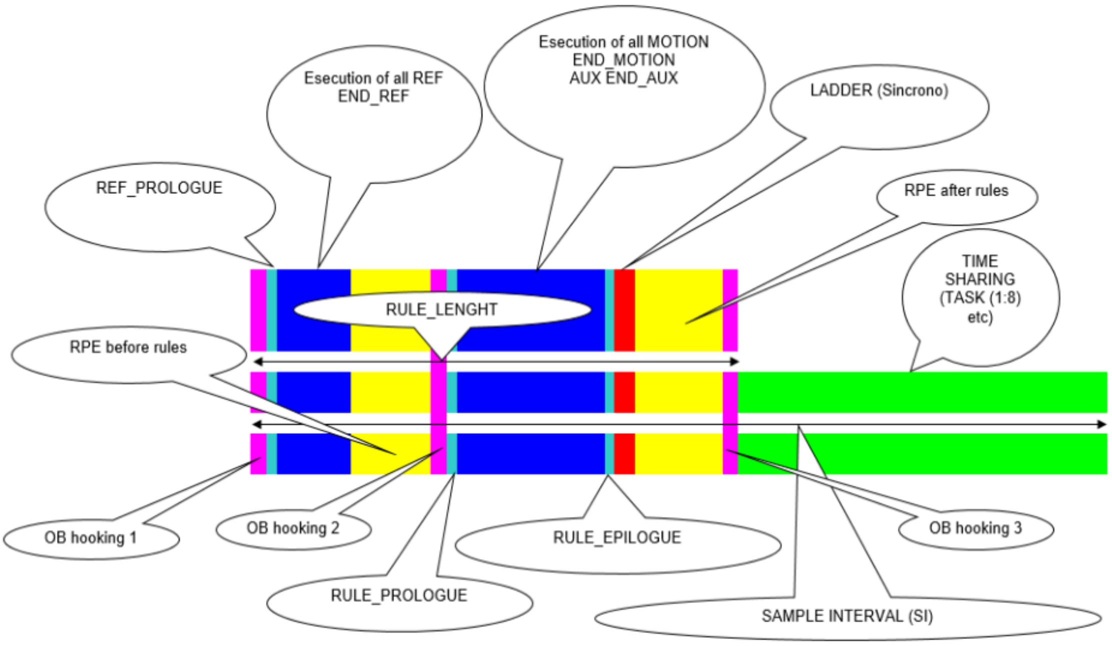


Figure 5.1: RTE multitasking

Priority	Task type
7	TASK in BACKGROUND (time-sharing) They are 8 low priority tasks written in the R3 language, used for not time consuming functions (for instance the management of the machine logic). Task 1 ($TASK1) represents the program entry point. This task will enable/disable the other tasks (see the instructions **mt_en** and **mt_dis**). The typical architecture of these tasks consists in an initialization session followed by an endless loop where the different operations/tasks of the controlled machines are performed. The correct evolution of these tasks is ensured by RTE. If any misbehaviour occurs, alarm **9113** User Task(t.s.): reduced freq. <Tname> will be output. Any information on the length and frequency are at the programmer's care (**loop_time**). With device command **ts_per_override** and **ts_nst_override** is possible to display /overridedi default settings
6	**LOW PRIORITY LADDER TASKS** Ladder task whose execution frequency is programmed by the user (1Hz÷2000Hz). Its length can be viewed through the predefined variable **ltl_length**
5	OB service.
4	RULE_PERIODIC RULE executed at a frequency programmed by the user. As the priority of this rule is lower than the one of the other RULES, its execution is subject to jitter, whose max length will be equal to the time required by RTE to execute the tasks with higher priority (RULE + SYNCRONOUS LADDER TASKS + HIGH PRIORITY LADDER TASKS + TASK ON EVENT, iif present).
3	**NORMAL PRIORITY LADDER TASKS** Task written in Ladder language whose execution frequency is programmed by the user (1Hz÷2000Hz). Its length can be viewed through the predefined variable **ltl_length**
2	RULES (fixed frequency functions -interrupt-) Tasks written in R3 language, reserved to the path building, to the descriptions of the links among the different axes and to the execution of the feedback algorithm (loop closure) RTE can execute up to 32 RULES (RC) in the same system interrupt. The selection of the RULES to be executed is done with the instruction **GROUP**, while the execution sequence can be programmed with the instruction **ORDER**. The rules execution frequency can be programmed with the instruction **RULE_FREQ** (in the range 25Hz÷2000Hz). With the CPU P2020 its max frequency is 5000hz. Its length can be viewed through the predefined variable **rule_length** **RULE_INIT** RULE executed just once, before the execution of the other RULES. It is executed the first time the instructions **ORDER** or **GROUP** is invoked. No RULE is active until the GROUP instruction has been executed or the predefined variable **RC** is set. If you wish to execute a **rule_init**, for instance to activate a **rule_prologue or epilogue** even in absence of rules, use the keyword **rule_start_norc**
2	**SYNCHRONOUS LADDER TASK** Task written in Ladder language, executed (if present) together with the RULES. Its length can be viewed through the predefined variable **ltl_length**
1	TASK ON EVENT They are particular tasks written in R3 language with max system priority and which are used to solve some particular requirements. The enabling events are: *Variation edge of a digital input (**INT_INP**) *Set frequency (**INT_TIMER**) *Time delay (**INT_AFTER**) Any RTE running operation is interrupted to handle these events (a typical latency is 40us). Consequently we advise the user that an excessive use of this performace can result in a degradation of the system's normal performance.
1	**HIGH PRIORITY LADDER** Task written in Ladder, whose execution period(PERIODO DI ESECUZIONE) is set by the user (1Hz÷2000Hz). Its length can be viewed through the predefined variable **ltl_length** Any RTE running operation is interrupted to handle these events (a typical latency is 40us). Consequently we advise the user that an excessive use of this performace can result in a degradation of the system's normal performance.

Figure 5.2: Priority

Single rule actions:



Function	Description
OB hooking 1	Object Blocks hooked hook1
REF_PROLOGUE	Optional function which, if defined, is first executed when a system interrupt occurs (and threfore it has less gitter with respect to the sample interval SI)
REF	Depending on the active RULES, all the REF, END_REF fields for the axes defined in such rules are executed in order to generate the driving reference (result of the option loop)
RPE	Handling of a group of axes by RPE with selection "before the rules"
OB hooking 2	Object Blocks hooked hook2
RULE_PROLOGUE	Optional function which, if defined, is executed immediately after the REF fields
MOTION, AUX	MOTION Generation of new kinematic variables for the axes (IP or IV or IA) The distinction between MOTION and AUX is only conceptual and is adopted by particularly meticolous programmers
RULE_EPILOGUE	Optional function which, if defined, is executed immediately after the MOTION AUX fields
LADDER SINCRONO	SYNCHRONOUS LADDER TASK. Use the command LAD_STATUS to get information on the execution timing
RPE	Handling of a group of axes by RPE with selection "before the rules"
OB hooking 3	Object Blocks hooked hook3

Figure 5.3: Rule execution

6. RDE - Robox Development Environment

6.1 First step

In order to getting started with the controller, we need a memory card where we have to copy RTE and some configuration file. A new memory card will have the folder KEY that is generated by Robox for license.

After the installation of RDE, RCE and Icmap we need to copy in the installation folder the license in order to compile programs. The license is provided by Robox.

Before creating a new project, a workspace have to be created. A workspace may contain more than one project. In the menu bar, the workspace menu, allow to open, create and manage workspaces, also to access the predefined examples .

6.2 New RTE project

6.3 Tools

From the workspace we can access the tools provided by RDE. Different king of tools are provided to debug and monitor the software: panels, oscilloscope, variable monitors and command shell.

6.3.1 Command shell

The shell allow to interact with the controller via shell commands and device commands. The most important commands for debugging are sysinfo to get information about the

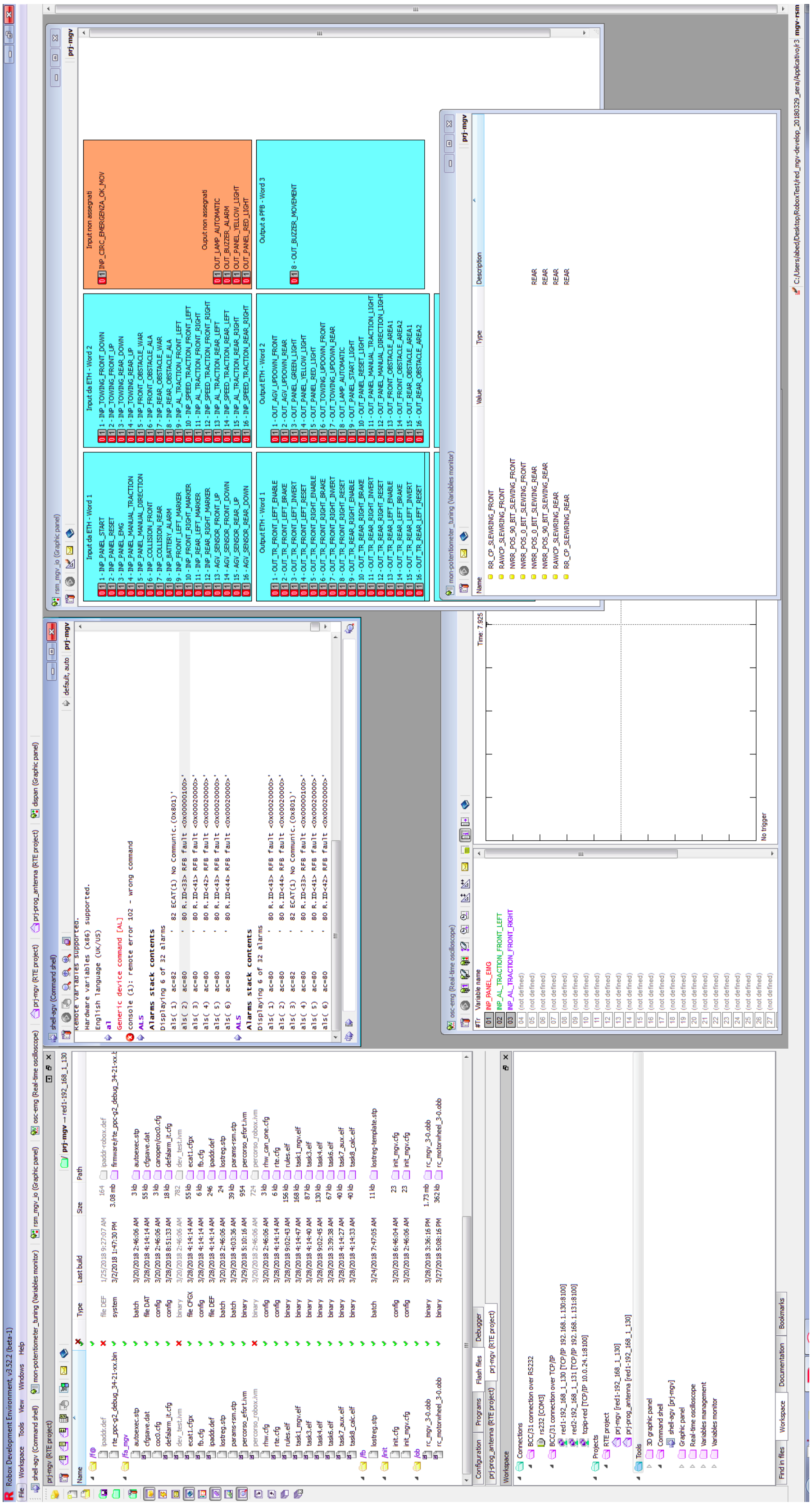


Figure 6.1: RDE main windows

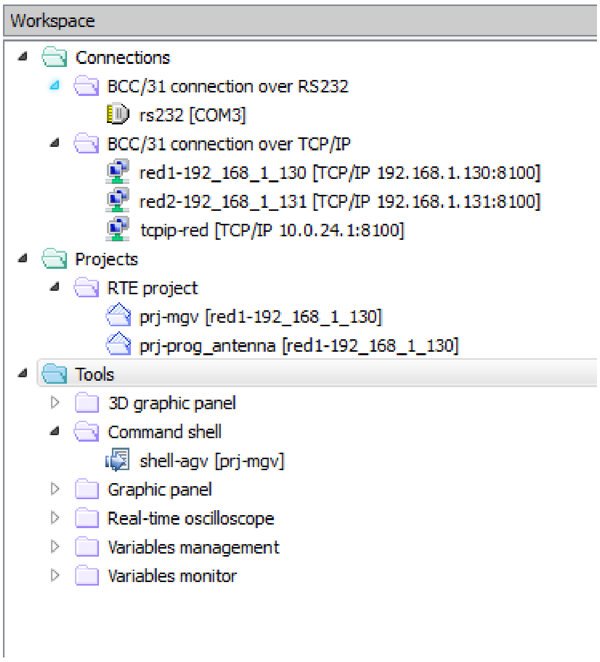


Figure 6.2: Workspace

controller, als to get the list of alarms in the stack and mreport to get a report about the activities of the controller, the result is a log menu that can be exported to text file..

We can make shortcuts to the most used commands. Click the mouse right button and go to set quick commands in order to define shortcuts. A list of defined shortcuts is available from the function keys [F1-F12] and from the action menu accessible from the mouse right click.

There are different types of commands, some types to manage variables others to manage the flash card other the device. A list of commands is available in the official documentation.

We will see some of the most used commands divided by category. Several commands can be used alone or with options. More than one command can be sent together by using the & operator. Take a look at fig.6.3 in order to see the usage and syntax of some commands.

Variable management

DV: Display variable value. The dv command allow us to monitor the value of variables e.g. dv nvr 1 display the value of the register nvr(1).

SV: Set variable value

FV: Force variable value

RV: Release variable value

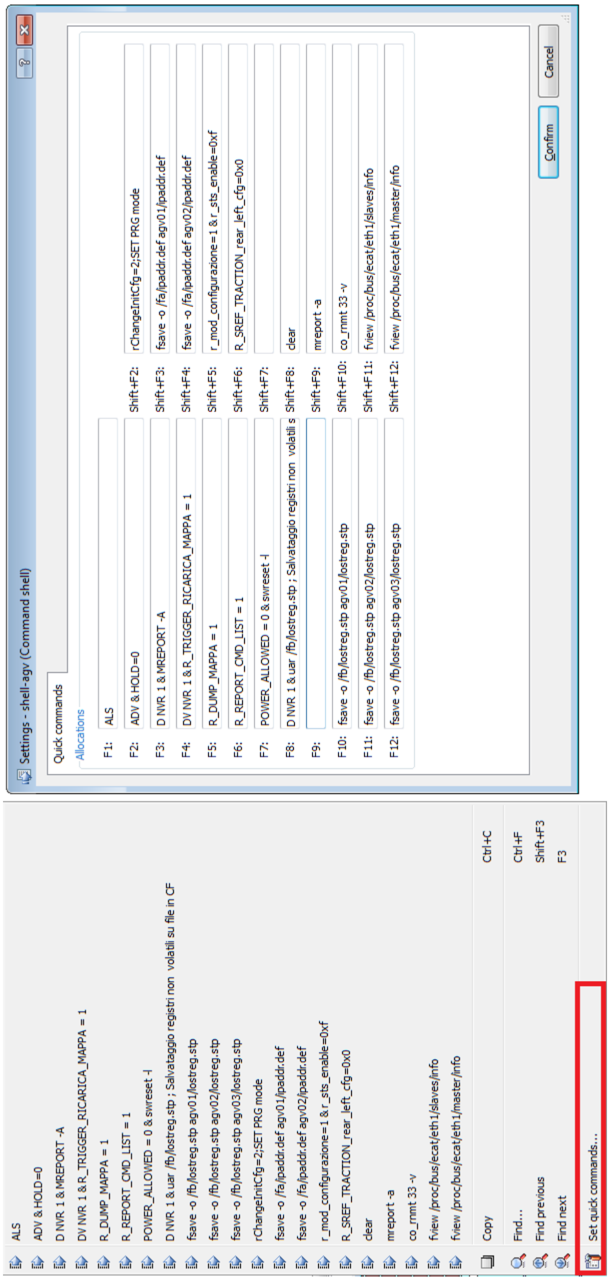


Figure 6.3: Command shell: Quick commands

Device management

adv: Resets the device alarm

sysinfo: Get information on connected device.

mreport: It displays the events log. the option -a display all reports. Other options are available in order to filter the report.

als: It displays the contents of the alarms stack.

swreset: Request for software reset.

uar: Opens a file present in the flash card and refreshes the assignments to R, NVR, RR, NVRR, SR and NVSR with the current values but leaves the comment lines unchanged.

Flash management

fsave: Save file from flash.

fview

Example of use

nvr 1 5 Set the value of nvr register 1 to 5, equivalent to sv nvr 1 5

nvr 4.2 1 Set the bit 2 of nvr register 4 to 1

d inp_w 100

d inp 1

d nvr 1

d nvr 2.3

d nvr 1 5 Displays 5 registers starting from 1

d nvr 1 5 -v Displays 5 registers starting from 1 with their index

f_inp 300 Force logical state of input 300

uar /fb/lostreg.stp Save the value of register in the file lostreg.stp

6.3.2 Oscilloscope

6.3.3 Graphic panel

6.4 Hardware configuration

6.4.1 Important folders and files

Add new folder fig.6.4

rte-xxxx.bin

rte.cg

ipaddr.def

rhw.cfg

lostreg.stp

init.cfg

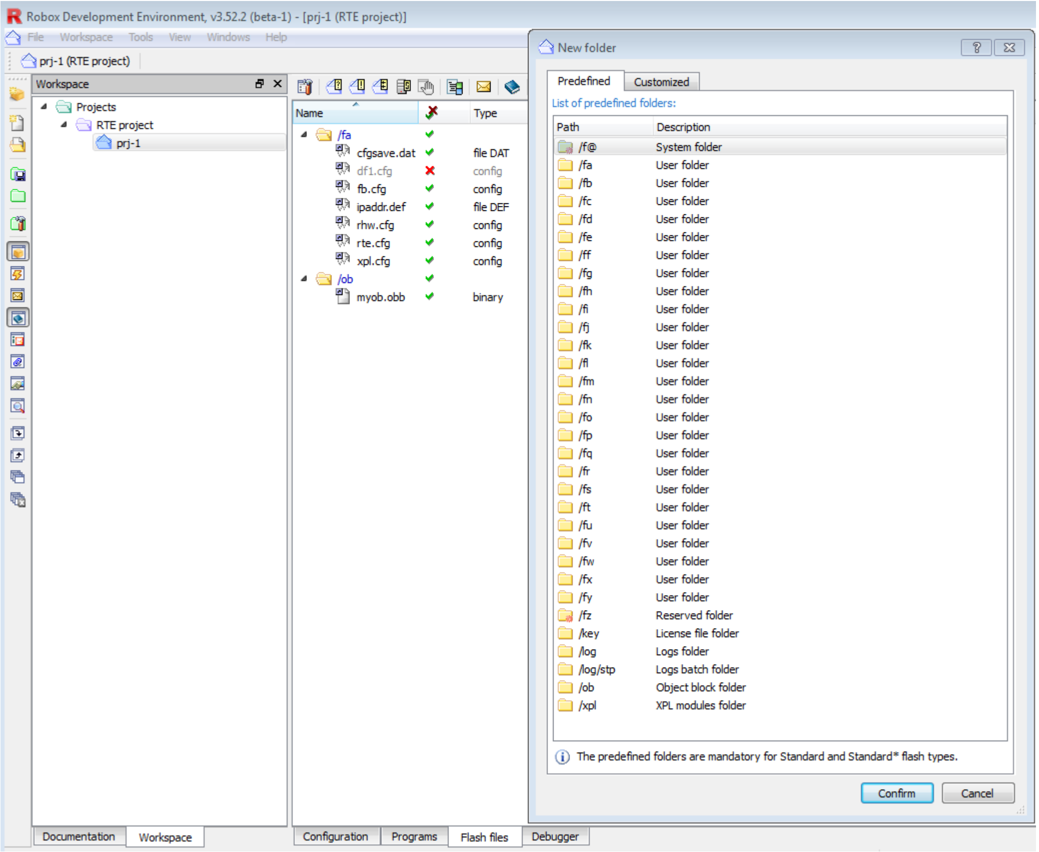


Figure 6.4: Add new folder to flash memory

defalarm_it.cfg

6.4.2 Registers

fig.6.5 show different types of registers and their allocation in memory.

6.4.3 Bus configuration

6.4.4 Axes configuration

6.5 Programming languages

6.5.1 R3

6.5.2 Predefined variables

There are different predefined variables in R3. (put every vairable in its context)

fr feed rate

kff feed forward factor

pro_gai position loop proportional gain

epos position error when the position loops are closed with a predefined formula

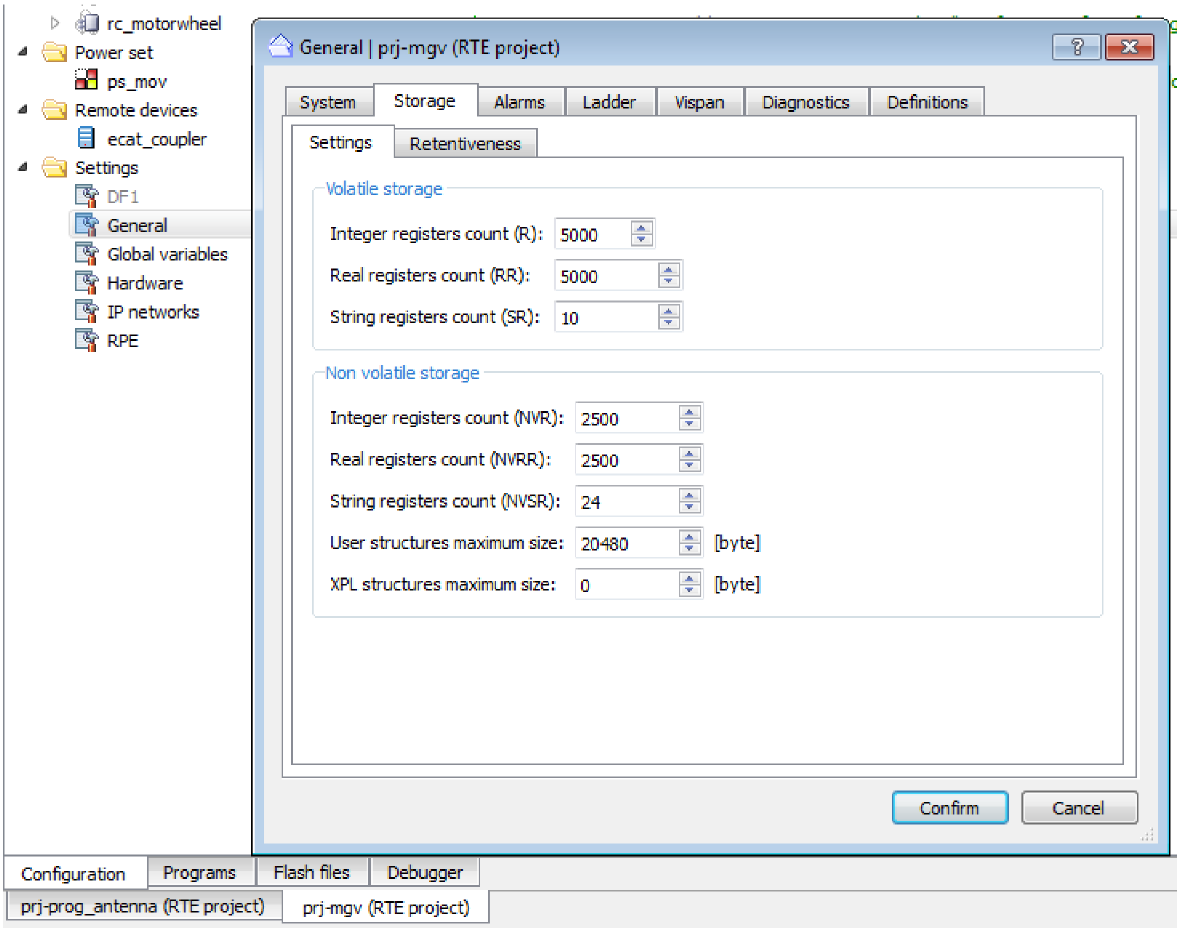


Figure 6.5: Register dimension

6.5.3 Object block

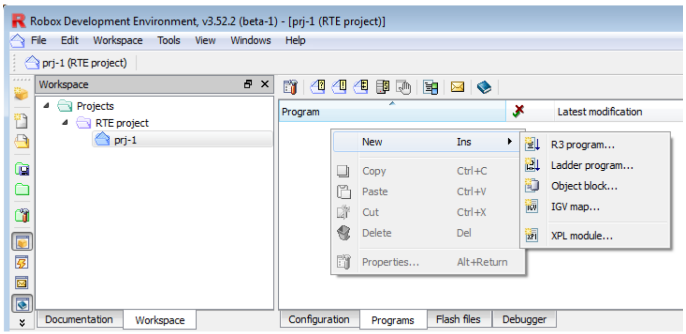
Object block is a C++ class, it is another option to write program in RDE. It is composed from a header file and a source file like like any C++ class, in addition to these classic files, RDE use the obs file to describe the interface of the Object block.

In rte project, right click and add new Object block fig.6.6. A folder have to be selected for the complied file. If the folder ob dosen't exist add it in the flash memory, see section files and folders.

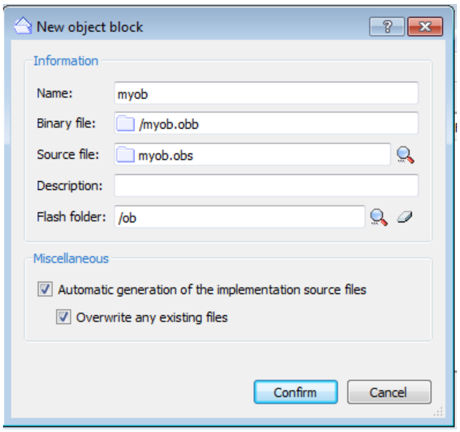
After the creation of a new object block we will obtain 4 files:

1. obs : object block interface file
2. h : C++ header
3. cpp : C++ source
4. obb : Object block binary file (compiled file)

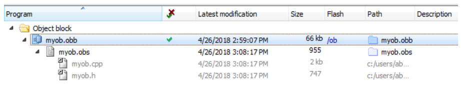
Fig.6.7, 6.8 and 6.9 show the auto generated files. As we can see the header and the source files have the structure of a classic C++ class with class name, class constructor and destructor.



(a) Create new Object block. right click in the tab program of an RTE project



(b) Write the OB name, select the folder of destination and check at least the first option.



(c) Object block structure files

Figure 6.6: New object block

As any class of an object oriented language, an Object block have methods (functions) and fields (variables). Public methods and fields that can be accessed from an R3 program should be written in the obs file respectively in the methods and properties blocks. Properties could be only of simple C++ types: BOOL, I8, I16, I32, U8, U16, U32, INT, FLOAT, REAL, CHAR,could not be of struct type. The source file where the code is implemented is written in the block implementation. Fig.6.10 show an example of an obs file.

As any object oreinted language, a class have to be instantiated before using it. In the configuration tab of an RTE project, right click Object block and add OB class or OB instance, fig.6.11. A class could have more than one instance. An OB is similar to an FB (Function block) in PLc programming.

Suppose we have the class rc_mgv and its instance agv, as in fig.6.11. We can call in R3 the method get_status of the class rc_mgv as we call it in C++: agv.get_status(AgvStatus_t4). We can access properties using also the dot operator for

```
;==============================================================================
;
; ROBOX SpA
; Via Sempione 82, Castelletto Ticino, ITALY
; +390331922086
; http://www.robox.it
;
;------------------------------------------------------------------------------
; Job number    :
; Title         : Class MYOB project
; Platform      : RTE
; Generator     : Robox Development Environment, v3.52.2 (beta-1)
;==============================================================================

define DEBUG_MYOB        ; Enable DEBUG for the class

object_block myob

    ; General object block information
    title
    version 1.0.0
    info

    end_info

    ; Class structures
    structures
    end_structures

    ; Class properties
    properties
        ; Use 'ro' data modifier for read-only properties
        ;     'ba' data modifier for bit access enabled properties
    end_properties

    ; Class methods
    methods
    end_methods

    ; Implementations
    implementation
        source "myob.cpp"
    end_implementation

end_block
```

Figure 6.7: Auto-generated OBS file

reading or writing: agv.DRIVING_MODE_TAPE = 4 or if(agv.TAPE_FOLLOW_LEFT).

If we defined a structure in the obs file we can use it to define a variable of that type in R3 using the dot operator.

OB Predefined example

In menu file, workspace, specials, predefined examples, we can find the example OB: Use and OB implementation. This example provide the source code an OB, rc_belt, that handle a belt and a rules and task 1 implementation. The Class rc_belt is an OB that can be find in the Object Block library. The example use another OB from the standard library, rc_axis, without providing its source code.

Refer to the official Object Block documentation for more informations about OB classes.

In the obs file of rc_belt, we can see the interface of the Class, how to use another class by importing it, define inputs and outputs and some methods. Note that input and outputs deffer only with the keyword ro. When an property is declared as read only behave like an

```
//==================================================================
//
// ROBOX SpA
// Via Sempione 82, Castelletto Ticino, ITALY
// +390331922086
// http://www.robox.it
//
//------------------------------------------------------------------
// Job number   :
// Title        : Class MYOB declaration
// Platform     : RTE
// Generator    : Robox Development Environment, v3.52.2 (beta-1)
//==================================================================

#ifndef __MYOB_H__
#define __MYOB_H__

#include <myob_base.h>

/*
 * Class MYOB declaration.
 *
 */
class myob: public myob_base
{
public:
    /* Class constructor */
    myob(rObOptions *opts);

    /* Class destructor */
    virtual ~myob();
};

#endif // __MYOB_H__
```

Figure 6.8: Auto-generated C++ header

output, otherwise behave like an input.

In the implementation we can see the call to two C++ source files. In this OB, 2 classes were defined. The class rc_belt, that inherit from rc_belt_base, and the class RCBelt.

A detailed example about OB implementation will be provided in the chapter related to motion control.

6.6 RTE project

6.6.1 Tasks

6.6.2 Rules

6.6.3 R3 example

6.6.4 OB example

6.7 Axis control example

6.7.1 Axis configuration

6.7.2 Power set and power handling

6.7.3 Velocity control

6.7.4 Position control

```
//===================================================================
//
// ROBOX SpA
// Via Sempione 82, Castelletto Ticino, ITALY
// +390331922086
// http://www.robox.it
//
//-------------------------------------------------------------------
// Job number   :
// Title        : Class MYOB implementation
// Platform     : RTE
// Generator    : Robox Development Environment, v3.52.2 (beta-1)
//===================================================================

#include <ob/reprintf.h>
#include "myob.h"

OB_FACTORY (myob)
    OB_INSTANCE (myob)
OB_ENDFACTORY

//===================================================================
// myob
//===================================================================

myob::myob(rObOptions *opts): myob_base(opts)
{
#ifdef DEBUG_MYOB
    reprintf("myob %p: created", this);
#endif

    // TODO: initialization code here
}

//-------------------------------------------------------------------

myob::~myob()
{
    // TODO: termination code here

#ifdef DEBUG_MYOB
    reprintf("myob %p: destroyed", this);
#endif
}
```

Figure 6.9: Auto-generated C++ source

```
define DEBUG_DYNCLASS       ; Enable DEBUG for the class

object_block dynclass

    ; General object block information
    title
    version 1.0.0
    info

    end_info

    ; Class structures
    structures
    end_structures

    ; Class properties
    properties
        ; Use 'ro' data modifier for read-only properties
        ;     'ba' data modifier for bit access enabled properties
        real torquedirection[6]
        real reductionratio[6]
        real ratedtorque[6]
        real al[6],a[6],d[6],th[6]
        real para1[17], para2[18], para3[12], para4[12], para5[12], para6[12]
        real loadparas[7]
        ;output
        real dyntorque[6]
    end_properties

    ; Class methods
    methods
        int caldyntorque(double q[6], double qd[6], double qdd[6])
    end_methods

    ; Implementations
    implementation
        source "dynclass.cpp"
    end_implementation

end_block
```

Figure 6.10: Obs example file

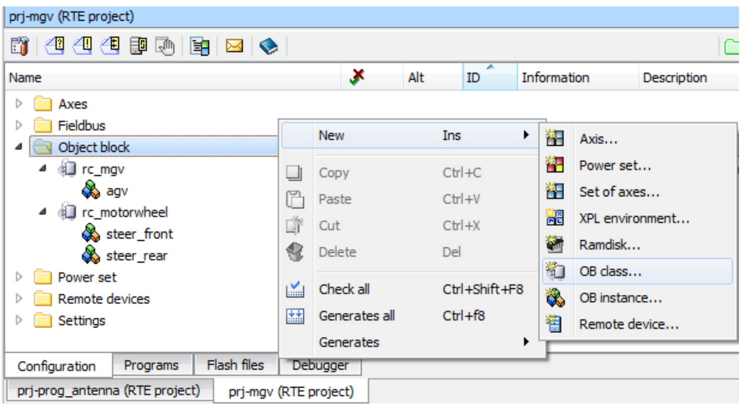


Figure 6.11: OB Class or instance. Add a class than add an instance. In the figure we can see 2 classes : rc_mgv and rc_motorwheel, and one instance of the first class and two instances of the second one.

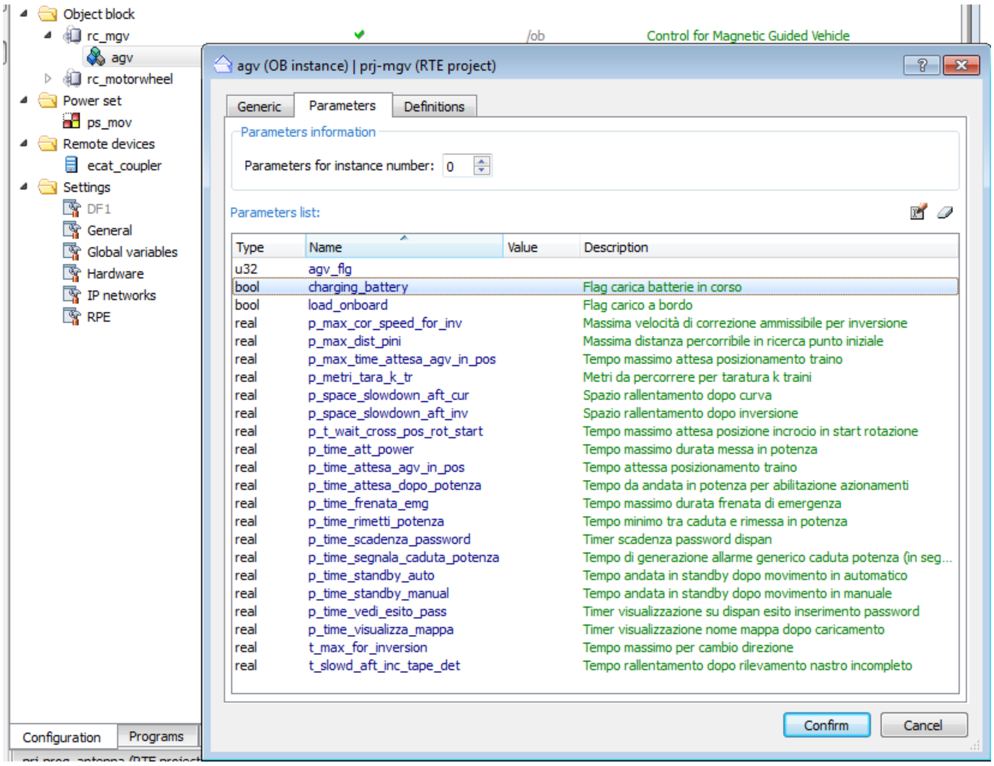


Figure 6.12: Object block instance parameters. In the column Value we can initialize the variables. To keep the program easy to read, it is better to initialize OB properties in R3. Note that properties declared as ro (read-only) are not shown here

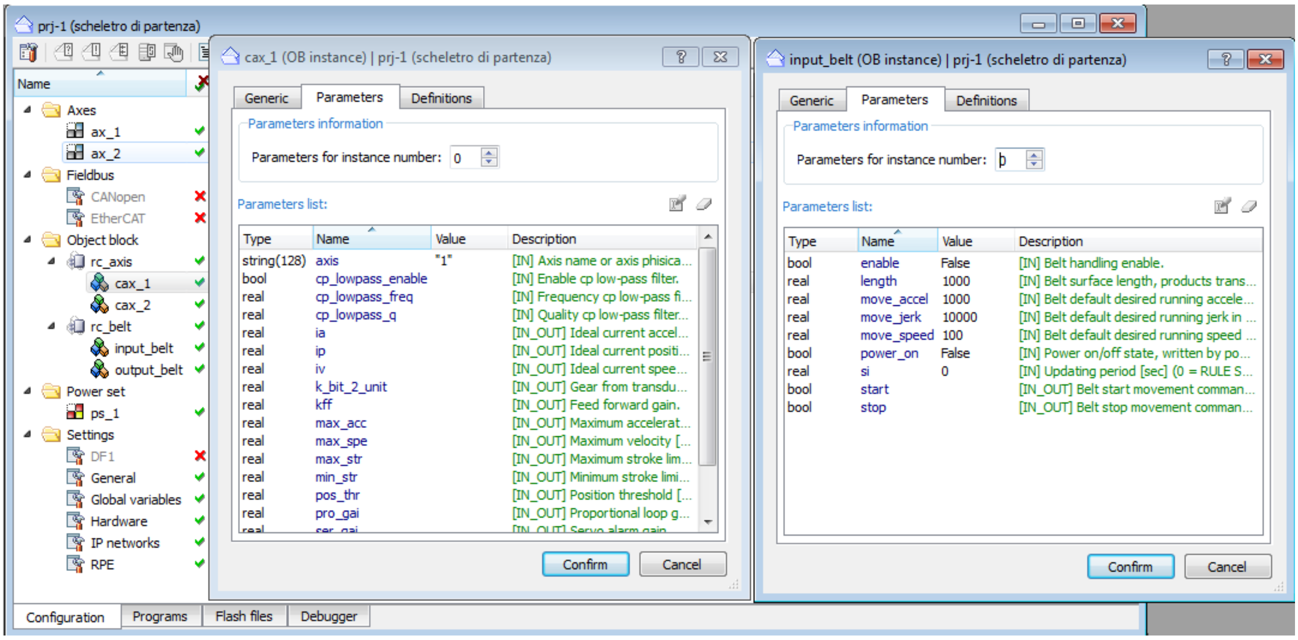


Figure 6.13: OB: Use and OB implementation predefined example.

7. Motion control

7.1 Basics

7.2 Example with R3

7.3 Example with OB

8. AGV commissioning

In this chapter we will see how to setup the parameters of the AGVs in RDE environment. Before doing it, we will have a look on mechanical and electrical part of the controller.

8.1 MGV mechanical and electrical part

In this section we will describe one kind of AGV, that is MGV a Magnetic guided vehicle. Some of the part of MGV are used in other king of AGVs. The difference is in the way of navigation and localization. The MGV have to follow a magnetic tap, using magnetic sensors. In this example the MGV use 4 magnetic sensors. Each magnetic sensor have 16 bits of output. The sensor is connected to a digital to canopen module in order to communicate with the controller.

In the middle of the MGV an RFID reader is placed. RFID cards are placed along the path on the magnetic tape, and are used as position feedback. The feedback is not continuous.

Four motors and 4 drives are present. The drives take a velocity reference from the controller via analog signal, and send a velocity feedback from an encoder. The encoder signal is read in the controller via a high speed counter. Some digital IO are exchanged between controller and drive like drive reset, drive enable, drive ready or not in alarm, etc.

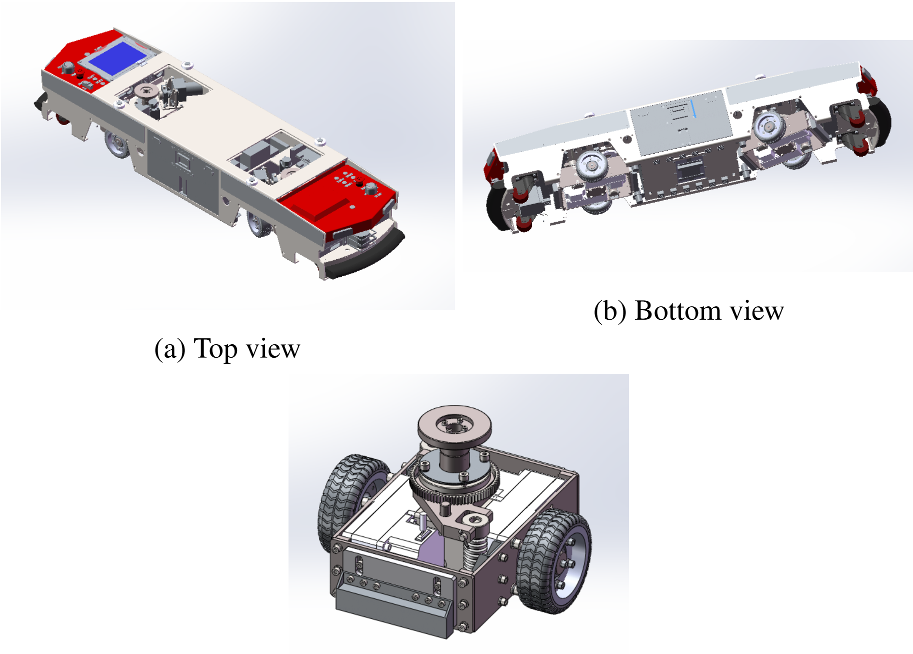
Steering is accomplished by modulating the speed of wheels. The angle of steering is relieved via a potentiometer, and read by the controller by an analog input module.

There are 2 laser scanner to monitor obstacles. Each laser scanner present 4 areas, that can be activated depending on the state of the AGV. Each area have 2 or 3 ranges of action.

The fist one, smallest one, is used as a safety stop of the AGV. The senond range, middle, is used to slow down the AGV when the laser scanner detect some obstacle, and the third one is used as warning. Ther laser scanner have 4 digital inputs and 4 digital outputs.

The AGV is powered by a batteries.

The communication between the AGV and AgvManager is done via an Ethernet to wireless device. The device is configured as access point. And the Ethernet to wireless device in AgvManager is configured as client.



(a) Top view

(b) Bottom view

(c) One set of wheels

Figure 8.1: Map line

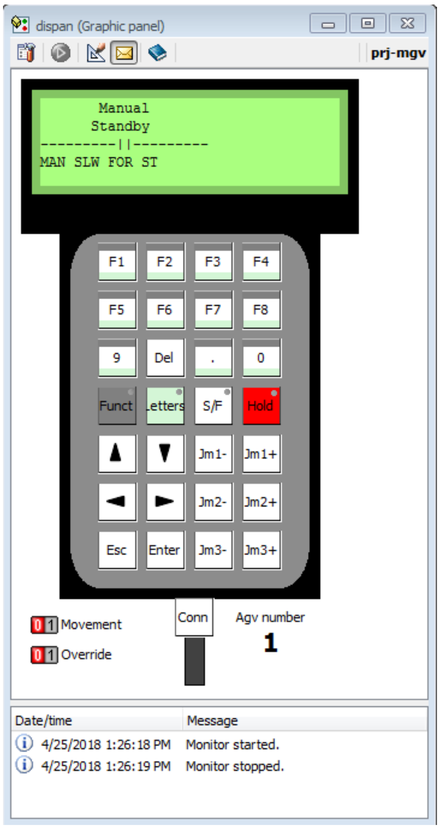
8.2 Dispan : Display panel

8.3 Commissioning

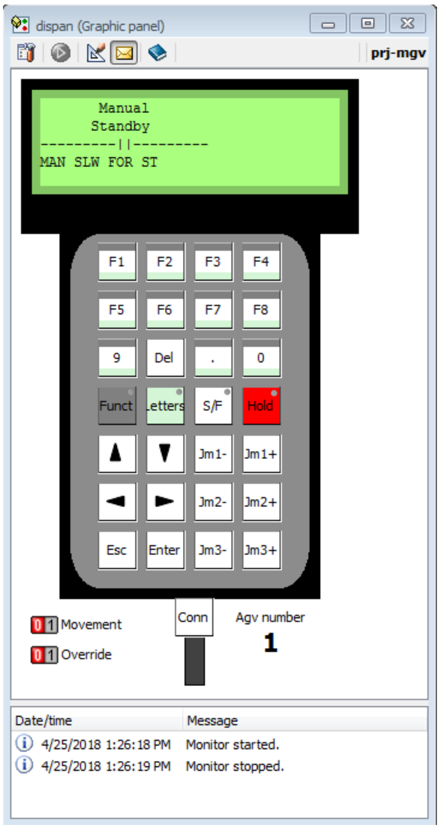
The first step in commissioning of any controller (plc or motion control) is to check the correct wiring of digital input and outputs. This step is relatively simple, using a variable monitor, online monitor or HMI we can debug the correct wiring of the signals following the electrical schematic.

Fig.8.3 show a template panel of IO signals for debugging purpose.

Once we are sure the electrical wiring is correct, we can proceed with tuning mechanical and eletrical components and software parameters.



(a) Dispan in RDE Graphic panel



(b) Physical Dispan, communicate with the controller via RS485

8.3.1 Potentiometer

This AGV have 2 potentiometers, every one is connectes to a set of two wheels. When a the 2 wheels connected to the same mechanical axes, rotate with different speeds, the set of wheels wil rotate arround the center of the wheels coordinate system shown in fig.8.4a. The angle of rotation is measured via a potentiometer connected to the origin of the coordinate system via an elastic joint.

The potentiometer used in this AGV have a range between 0 and 270 degrees. The AGV can steer between $-30°$ and $120°$. We have to set the potentiometer in a way that the tension between pin 1 and 2 is around $3V$ when the wheels angle is at $0°$.

After that we have to scale the analog input of the controller in order to read the correct angle. A linear relationship between the tension (or the raw value read by the analog input) an the angle in degree was supposed.

To adjust the parameters, we can use the dispan or a variable monitor. The procedure is to place the wheels at $0°$ then at $90°$ and read the corresponding value given by the analog input. Then assign the values to the variables NVRR_POS_0_BIT_SLEWING_*** and NVRR_POS_90_BIT_SLEWING_***. Of course that same procedure have to be done for both potentiometers the front and the rear one fig.8.4a.

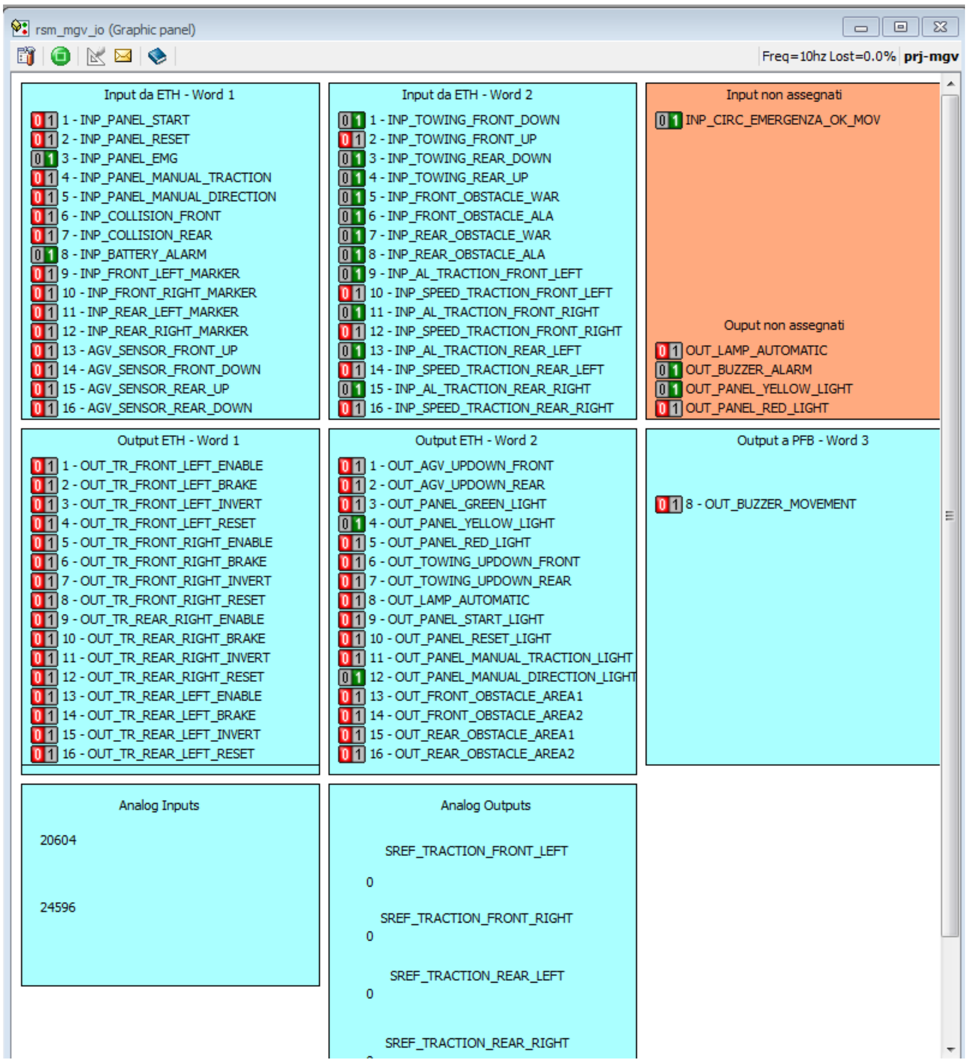
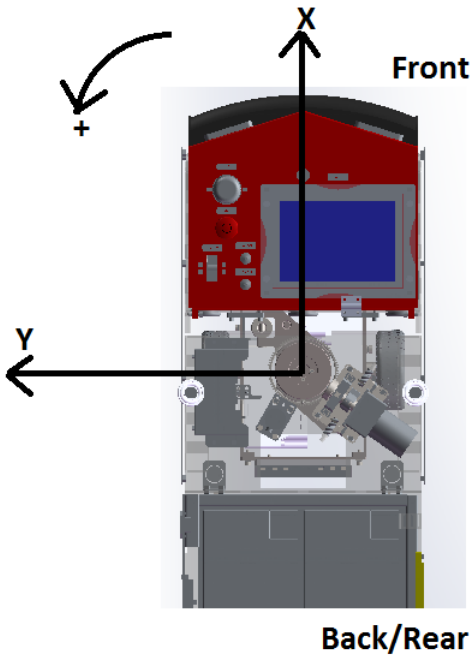
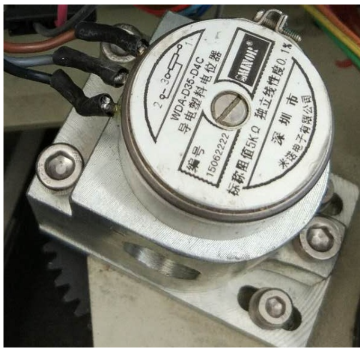


Figure 8.3: AGV IO signals. RDE graphic panel

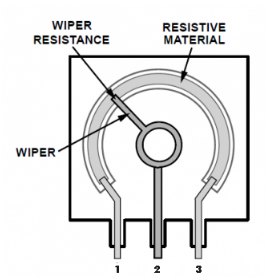
Using the dispan, we have to go to the voice F6 than choose 3 or 4 than save the parameters Figure.??.



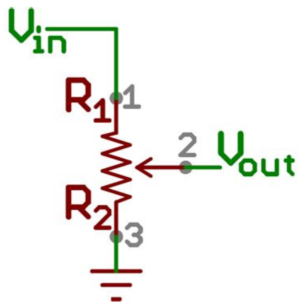
(a) AGV wheel coordinate system



(b) Potentiometer connected to wheel vis an elastic joint



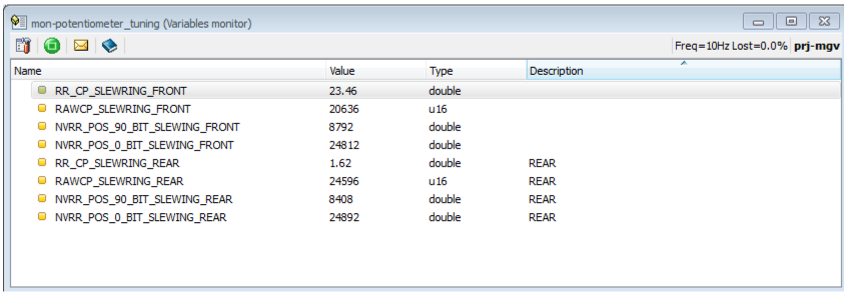
(c) Potentiometer construction



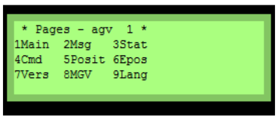
(d) Potentiometer schematic

In lisiting.8.1 is shown the code R3 that represent the relationship between the analog input and the angle in degree.

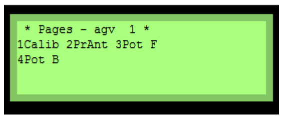
```
//  Read actual position of slewrings (steers)
//  NVRR_POS_0_BIT_SLEWING_FRONT = Position of front slewing axis at 0
    degrees in bits
//  NVRR_POS_90_BIT_SLEWING_FRONT = Position of front slewing axis at
    90 degrees in bits
//
if (NVRR_POS_0_BIT_SLEWING_FRONT <> NVRR_POS_90_BIT_SLEWING_FRONT)
   ScalaFront = 90.0 / (NVRR_POS_90_BIT_SLEWING_FRONT −
    NVRR_POS_0_BIT_SLEWING_FRONT)
  RR_CP_SLEWRING_FRONT = ScalaFront ∗ (RAWCP_SLEWRING_FRONT −
    NVRR_POS_0_BIT_SLEWING_FRONT)
```



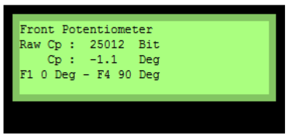
(a) RDE potentiometer variable monitor



(b) Dispan main menu, reached by F1



(c) Dispan 6Epos: Press 3 or 4 to tune the front or back potentiometer



(d) Front potenziometer tuning. Turn the Wheels to 0 degree then press F1. Turn the wheels to 90 degree than press F4.

Figure 8.5: Potentiometer tuning

```
else
  RR_CP_SLEWRING_FRONT = 999.9    // Error
endif

if (not range(CP(AX_SLEWRING_FRONT), MIN_STR(AX_SLEWRING_FRONT),
    MAX_STR(AX_SLEWRING_FRONT)))
   alarm_set(AL_WHEEL_RANGE, AX_SLEWRING_FRONT)
endif
//
//  NVRR_POS_0_BIT_SLEWING_REAR = Position of rear slewing axis at 0
    degrees in bits
//  NVRR_POS_90_BIT_SLEWING_REAR = Position of rear slewing axis at 90
    degrees in bits
;
if (NVRR_POS_0_BIT_SLEWING_REAR <> NVRR_POS_90_BIT_SLEWING_REAR)
   ScalaRear = 90.0 / (NVRR_POS_90_BIT_SLEWING_REAR -
    NVRR_POS_0_BIT_SLEWING_REAR)
  RR_CP_SLEWRING_REAR = ScalaRear * (RAWCP_SLEWRING_REAR -
    NVRR_POS_0_BIT_SLEWING_REAR)
```

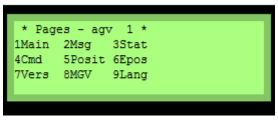
```
else
  RR_CP_SLEWRING_REAR = 999.9    // Error
endif

if (not range(CP(AX_SLEWRING_REAR), MIN_STR(AX_SLEWRING_REAR), MAX_STR(
    AX_SLEWRING_REAR)))
  alarm_set(AL_WHEEL_RANGE, AX_SLEWRING_REAR)
endif
```

Listing 8.1: Scale potentiometer analog input

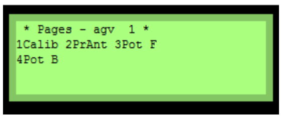
8.3.2 Magnetic sensors and Canopen modules

The 16 bits magnetic sensors are connected to canopen modules. Address have to be given to canopen modules, this can be done using the dispan and connecting every module to the CAN2 port of the controller, and the address is given one by one to the modules.

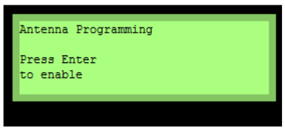
The figure fig.8.6 show the steps of the procedure.



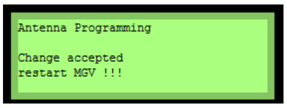
(a) Dispan main menu, F1



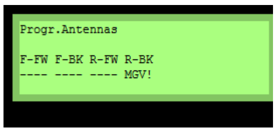
(b) Dispan F6 menu



(c) From F6 menu, press 2, to open the 2PrAnt page. Press enter to confirm



(d) Restart AGV



(e) After restarting AGV we can connect the canopen module to program them. When finsh press MGV to terminate and restart the AGV.

Figure 8.6: Magnetic sensor canopen programming

8.3.3 Laser scanner

Every laser scanner have 4 inputs and 4 outputs. These digital signals are 4 bit code to identify the active area and the requested area. In our example we use only two input and two outputs.

Photo-coupler input(Anode common, Each input ON current 4mA)
Setting detecting area changeover
Set area No. by [Input 1], [Input 2], [Input 3] and [Input 4]
Stop emission by getting all [Input 1], [Input 2], [Input 3] and [Input 4] to ON
(OFF : H level input, ON : L level input)

[Input 1]	[Input 2]	[Input 3]	[Input 4]	Area patterns
ON	ON	ON	ON	Emission stop
OFF	ON	ON	ON	Area 1
ON	OFF	ON	ON	Area 2
OFF	OFF	ON	ON	Area 3
ON	ON	OFF	ON	Area 4
OFF	ON	OFF	ON	Area 5
ON	OFF	OFF	ON	Area 6
OFF	OFF	OFF	ON	Area 7
ON	ON	ON	OFF	Area 8
OFF	ON	ON	OFF	Area 9
ON	OFF	ON	OFF	Area 10
OFF	OFF	ON	OFF	Area 11
ON	ON	OFF	OFF	Area 12
OFF	ON	OFF	OFF	Area 13
ON	OFF	OFF	OFF	Area 14
OFF	OFF	OFF	OFF	Area 15

Figure 8.7: PBS-03JN laser scanner area code

The model of laser scanner we use, have 16 areas. The binary code is shown in fig.**??**.

Four different areas will be defined depending on the state of the agv. For example if the agv is not moving the alarm range of the 2 laser scanner should be extremely small. If the AGV is going forward the range of the front laser scanner should be bigger than the rear lase scanner and viceversa. We can define also another range for curving depending on the position of fixed obstacles.

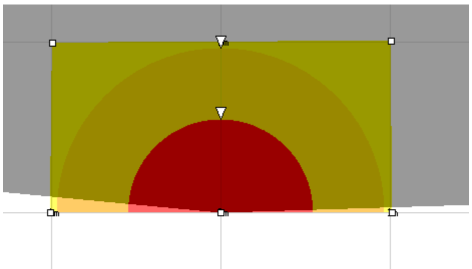
Areas are activated using the digital inputs of the laser scanner (controller outputs). Following the codification of the laser scanner model e.g. fig.**??**.

8.3.4 AGV parameters

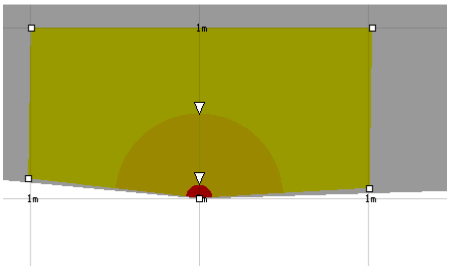
In task 1, AGV parameters file is loaded, the file name is written in register nvsr(1) NVSR_PLANT_CONFIG_FILE, by calling the function LoadAgvConfig(). We can create a parameter file called "params-rsm.stp" and assign the register nsvr(1) with file name.

In the parameter file we can find, the name of the map to be used, mechanical parameters listing.8.2, etc.

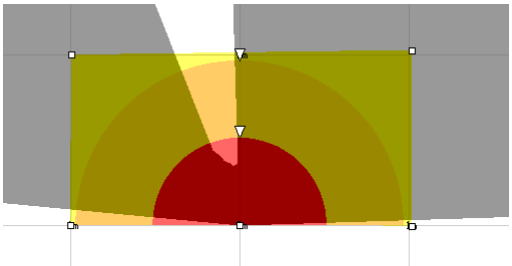
```
;
```



(a) Laser scanner area with big alarm range



(b) Laser scanner area with small alarm range. Active when AGV is not moving.



(c) Laser scanner area, obstacle detected in the alarm area. AGV will stop moving.

Figure 8.8: Laser scanner areas

```
; Registers for mechanical configuration
;
rr(100) 0.4185        ; RR_POS_SLEWRING_STEER_FRONT_X [m] X position of
    the center of the front slewring
rr(101) 0.0           ; RR_POS_SLEWRING_STEER_FRONT_Y [m] Y position of
    the center of the front slewring
rr(102) 0.1525        ; RR_RADIUS_SLEWRING_FRONT      [m] Distance from
    the center of the wheel composing the electronic front steer
rr(103) -0.4185       ; RR_POS_SLEWRING_STEER_REAR_X  [m] X position of
    the center of the rear slewring
rr(104) 0.0           ; RR_POS_SLEWRING_STEER_REAR_Y  [m] Y position of
    the center of the rear slewring
rr(105) 0.1525        ; RR_RADIUS_SLEWRING_REAR      [m] Distance from the
    center of the wheel composing the electronic rear steer
```

Listing 8.2: params-rsm.stp Mechanical paramter of the AGV

8.3.5 Register backup

Non volatile registers are stored in memory, when RTE is loaded it retrieve the values from the memory. It is a good idea anyway to backup the values of non volatile registers to a file, and load them in case of loss of memory.

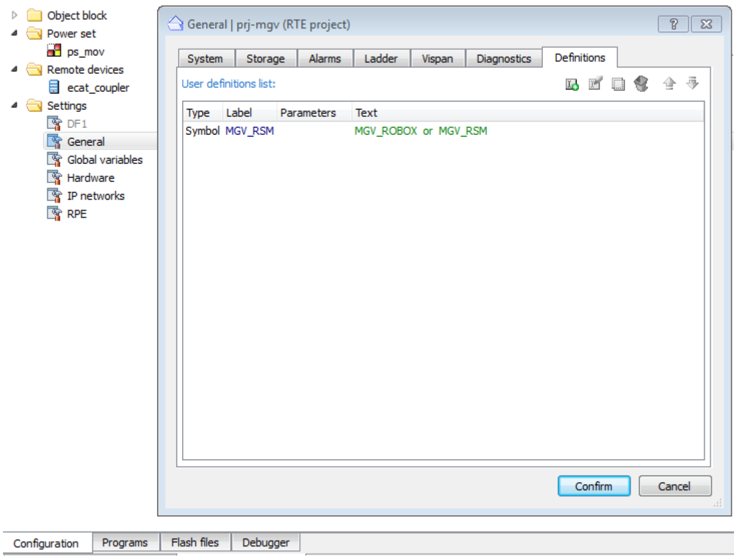
We can save the values of registers to a file by sending the command uar /fb/lostreg.stp. The file lostreg.stp is a file which contain desired register to be saved. For example if we want to save only the values of regiters nvrr(140) and nvrr(162) we write in the file only these. When calling the command uar, only these registers are saved. There is a template file that can be used as a starting point.

If RTE lose memory, it load the file /fa/lostreg.stp when needed, the operator have to confirm it. In the file /fa/lostreg.stp there is a link to the file /fb/lostreg.stp.

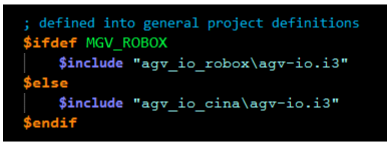
For example if we have more than one agv, with different register values, we can call the command uar for each agv then copy the file /fb/lostreg.stp to our computer, e.g. fsave -o /fb/lostreg.stp agv01/lostreg.stp , this command copy the file from /fb to the folder agv01 in the project directory.

8.3.6 General definitions

Variables defined globally, at project level fig.8.9a.



(a) Variable definitions, project level



```
; defined into general project definitions
$ifdef MGV_ROBOX
    $include "agv_io_robox\agv-io.i3"
$else
    $include "agv_io_cina\agv-io.i3"
$endif
```

(b) If the variable MGV_ROBOX is defined gloably, a file is included otherwise another one is included.

Figure 8.9: Global variable definitions

8.4 AGV ecosystem

8.4.1 Software and tools

The software needed to program and setup an AGV are:

1. Map generator : RAT can be used
2. AgvManager : Script and path planning
3. Compilers: RCE and ICmap compilers
4. RDE
5. Database : optional

The electronic hardware needed:

1. RP1 : Robox controller to control AGV
2. personal computer: Where AgvManager will be executed
3. Plc or RP1: As an interface with signals from the plant
4. Wireless switch to communicate between RP1 and AgvManager

8.5 AgvManager-RP1 communication protocol

8.6 Hardware configuration

8.7 Program description

The Agv program consist of 2 RTE projects: AGV program and antenna program. The antenna program is used only to program the address of canopen devices. The AGV program is used to control the agv and communicate with AgvManager.

The agv program is written in R3 and in Object blocks. The R3 program consist of 7 tasks and one Rule. And the OB program consist of 2 object blocks: one for wheel control, with 2 instances, and one for AGV with one instance. The ob for Agv is changed depending on the type of the agv. In this example we will use the mgv object block for magnetic guided vehicles.

Some logic is written in R3 other logic is written in OB. Important non volatile parameters are saved in the file lostreg.stp, this file is used as backup in case the memory of the agv is lost.

We already see how to set some parameters and value in RDE or in the dispan. AGV operations changes from plant to plant. The main logic, a part from improvements, still the same. Plant specific logic changes. These kinds of operations, that the AGV get from AgvManager have to be implemented in R3.

For example, if we need to implement the logic of the LOAD command operation from AgvManager we have to do it in rules–> function eseguiOperazioni(). The constant

O_LOAD have to be defined in the file operations.i3. The value of the constant should be equal to the value defined in AgvManager, that is 2.

III

Appendices

9 **External editors** 121
9.1 Vim
9.2 Notepad++
9.3 UltraEdit

9. External editors

In order to write a program, you can use the internal text editor provided by AgvManager and RDE. You can use also external editors, the one you like. RDE support 3 external editors, this mean that in the configuration window, you can choose to open the source code in an external editor. Notepad++, UltraEdit and ConTEXT are supported by RDE.

In the following section we will see how we make configuration files in order to highlight the syntax of Xscript, R3 language and object blocks.

9.1 Vim

File needed and where to place them

9.1.1 Syntax highlight

9.1.2 Function list

9.2 Notepad++

File needed and where to place them

9.2.1 Regular Expressions

Notepad++ regular expressions use the standard PCRE (Perl) syntax.

9.2.2 Syntax highlight

9.2.3 Function list

9.3 UltraEdit

File needed and where to place them

9.3.1 Regular Expressions

UltraEdit doesn't use Unix style regex. There are some difference between the two styles. On the website of UltraEdit, we can find the difference between them. In the wordfile of UltraEdit regex of UltraEdit should be used, it is different from the one used in Notepad++.

9.3.2 Function list and syntax highlight

IV

Bibliography