proANT

Autonomous Guided Vehicle

Technical Data Sheet

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Technical Specifications

proANT aAGV – Hardware	
Dimensions:	Individually fit to costumer and load to be handled e.g. ϕ 600mm, 800mm, 1000mm
Laser scanner:	SICK S300
Positioning technology:	Simultaneous Localization and Mapping (SLAM) with laser scanner, incremental motor encoders and a gyroscopic sensor
Drive:	Electric motor, 2 wheel differential drive and 2 free spinning wheels
Max speed:	1,5 m/s
Turning circle:	0 mm (turns on the spot)
Positioning accuracy:	In normal drive: 1°, +/- 5cm In reference drive[1]: 1cm
Load:	Up to 200kg (aprox. 450lb)
Load handling:	Specific to the load to be handled. e.g. Floating conveyor for heavy boxes, rolling conveyor for commissioning containers, gripping system to pull rolling trollies etc.
Height of load transfer:	Individually fit to costumer's requirements. One robot can handle different loading heights.
Vehicle handshake with docking & transfer stations:	Triple eye
Battery:	8 cells LiFeYPO4 with balancing boards and temperature monitoring, 24V DC, 40 or 60 Ah.
Battery life:	3-5 years
aAGV availability (transport time / charging time)	> 80%

[1] Reference drive: the robot drives to a defined reference point, usually a steel triangle on a production machine.

Opportunity charging[2]	Supported
Certifications:	CE & UL (Certified for interaction with humans)

proANT aAGV – Software & Communications	
Software components:	AGV Interface controller (AIC) Fleet Management Software (FMS) aAGV Core Software Battery Management Software (BMS)
Medium of communication:	WLAN (encrypted with WPA2)
Transport order generation:	Fit to costumer's needs. Possible options: • Out of ERP or MES program (e.g. SAP) • Using buttons • Using a touchpanel on the aAGV • Using costumer's database (e.g. MS SQL, Oracle)
Software core:	Own software development based on the Robot Operating System (ROS). After project completion, all software sources are handed to the costumer.
Interface to infrastructure	Supported (i.e. elevators & fire protection doors)

InSystems - Delivery and Service Strategy	
Software updates:	Can be transmitted remotely.
Lead time from purchase order:	26 including customization and engineering. 8 weeks to repurchase.
Service strategy:	Usually a service agreement is set up. The service contains software support during day times and regular check of the aAGV's hardware components (every 6 months).
Warranty	2 years

[2] Opportunity charging: frequent charging for brief period of time (e.g. on a production machine or buffer that is often targeted)

Relevant technical explanations and examples

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1 Navigation

1.1 Self-localization

A basic prerequisite for autonomous mobile robots is self- localization. The robot needs to know where it is in order to behave intelligently.
For relative positioning, each proANT uses an odometric system based on an incremental encoder of the drive wheels to measure the traveled distance, and a gyroscopic sensor to measure the relative angle of the robot in space.

Since these measurements are not very precise, they are backed by the information from the SICK laser scanner. As a setting-up operation, one robot from the fleet is moved around manually (e.g., by joystick) in the environment in which the robot shall operate later on. During this initiation, all distance profiles from the laser scanner are recorded and combined with the data from odometry. From this, a map is produced which reflects the contours of objects as sensed by the scanner. This map is downloaded from the robot and manually edited. A graphical editor is used to add one-way passages and no-go-areas to the map. Moreover, target positions (unique name, coordinates and approaching angle) are added to the map. The edited map is uploaded to every robot in the fleet.

Upon start-up, each robot starts an initial localization to determine its current position. This is done by comparing the currently received distance profile from the laser scanner with a coherent fraction of the map.
During autonomous operation, the localization algorithm is triggered at regular intervals, depending on the information about the traveled distance from odometry. This way, the robot is constantly aware of its own position within the mapped area.

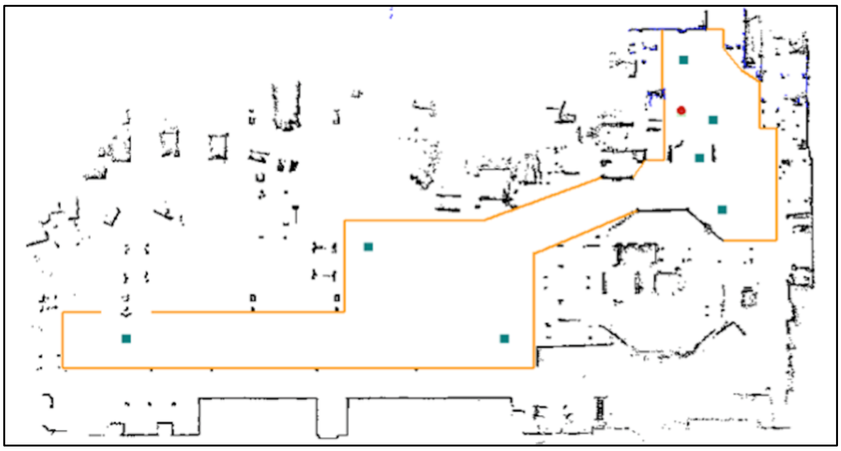

Figure 1: Map with outlines, no-go-areas and target locations (green).

1.2 Route planning

During autonomous operation, the robot has to travel to specific target locations. It thus has to find the optimal route from its current position to this target location, given the map which determines the accessible floor space.

An important factor for route planning is the size of the robot, i.e., its width in the direction of motion. The map is divided into squares which are a fraction of the robot size. From the map it is determined whether a square is drivable or in a no-go-area. All no-go-squares and adjacent squares up to half of the robot size are marked occupied and exempt from path planning. For all remaining squares, a cost is calculated which decreases with the distance to occupied squares. Then, a path is calculated which constitutes a smooth spline function through the lowest cost squares.

Since the robots are operating in a dynamic, real-life environment, they have to be able to react to unexpected obstacles and road blocks. If the robot during its trip detects an obstacle which is not in the map, the corresponding squares are marked temporarily occupied, and costs are recalculated. Since the robot keeps moving towards the obstacle, the cost function is dynamic, respecting current speed and acceleration. This dynamic guarantees a fast travel towards the destination, while at the same time avoiding collisions.

Figure 2: Robot with planned path

1.3 Automatic Guided Vehicles (AGV) vs Autonomous Guided Vehicles (aAGV)

Autonomous Guided Vehicles (aAGV) are a development of traditional *Automatic* Guided Vehicles (AGV) and offer significant advantages. While conventional AGVs are guided by inductive coils or reflectors, aAGVs navigate with complete freedom.

This has a substantial impact on the integration of vehicles into a factory layout. While AGVs require the mounting of guiding references such as rails or reflectors, aAGVS can be integrated into plants without the need of modifications. This also applies to changes in the transport route. While setting up a new transport goal or source is a major project when using traditional AGVs, with ProANT aAGVs it is a matter of a few hours.

The implementation of aAGVs also reduces the risk of outage. The need of guiding references in a traditional AGV system increases the amount of required hardware and therefore the risk of failure. As an example, a damage in a single reflector can cause the entire transport system to break down. ProANT aAGVs don't require much further hardware as the robot itself, and therefore minimize the risk of failure.

A further advantage of aAGVs is the behavior in response to obstacles. While obstacles in the track of traditional AGVs produce a halt of the vehicle and subsequent jamming, aAGVs simply navigate around the obstacle and seamlessly continue their operation.

In summary, aAGVs offer a high amount of flexibility with increased efficiency and are therefore a convenient substitute to traditional AGVs.

	AGV	**aAGV**
Navigation	Guided (rails, reflectors etc.)	Free
Integration / Changes	Expensive	Simple
Response to obstacles	Halt / Jamming	Obstacle Avoidance

2 Safety Components

2.1 Collaborative interaction

proANT aAGVs are safe to collaborate with humans. This means that the robots can fully work together with factory workers without the need of implementing safety fences or splitting the available transport routes.

The proANT aAGVs are certified by CE and UL. The CE certification guarantees that the vehicles comply with the restrictive European safety directives such as the EN1525 (*Safety of industrial trucks - Driverless trucks and their systems*)

2.2 Protective and safety fields

proANT aAGVs interact and travel on the same path as humans. This makes safety an important issue. In order to always maintain safety during travel, various protective and safety fields are implemented into the aAGV's driving routines.

When an obstacle enters the proANT's *warning* field, the aAGV lowers its speed and starts to drive around the obstacle.

When an obstacle enters the proANT's *protective* field the aAGV goes into an abrupt stop and waits until the obstacle exits the protective field.

The combination of the SICK laser scanner and encoders on the aAGV's wheels make it possible to dynamically adapt the field's sizes to the aAGV's actual driving speed. This greatly increases the proANT's driving dynamics while maintaining the capability to always avoid obstacles or come to a halt when a perilous situation arises.

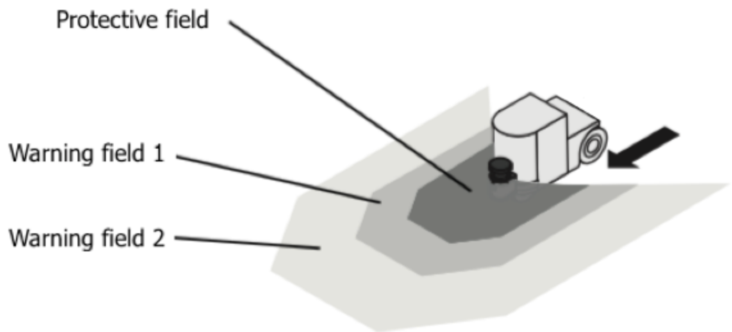

Figure 3: proANT aAGV's protective and safety fields

2.3 Hardware handshake

A hardware handshake is used to ensure safety when handing over the load between proANT and conveyor station. The hardware handshake verifies that the aAGV is actually standing where it should before a load is handed over.

As a means of hardware handshake, the *triple eye* system has proven reliable. The triple eye system consists of three laser emitters and receivers. Only if the vehicle is standing correctly, all laser pulses are received and the load handling can begin.

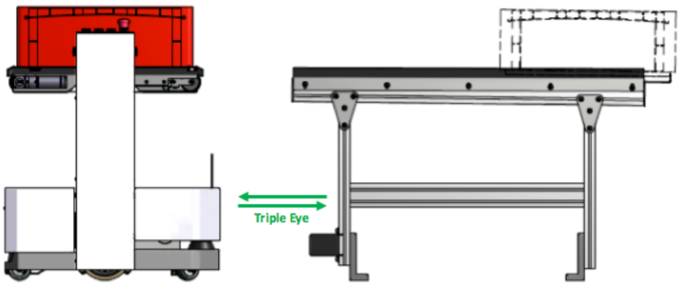

Figure 4: Hardware handshake using triple eye (handshake not yet reached)

3 Battery

3.1 Battery Specifications

Lithium-Iron phosphate (LiFeYPo4) batteries are built into the proANT aAGVs. These are an advancement to the Lithim-Ion battery. LiFePo4 is used cathode material, which is doped with Yttrium to increase technical characteristics such as power and durability. The battery is a dry battery.

Lithium-Iron phosphate is not hazardous nor inflammable. The LiFeYPo4 cells support high charging currents and virtually don't self-discharge. In comparison to conventional Li-Ion batteries, LiFeYPo4 does not segregate metallic lithium nor oxygen when overcharged. These batteries don't possess a memory-effect, enabling them to have a great longevity when used adequately.

Due to the support of high charging currents, LiFeYPo4 batteries can be charged in a short timespan. The most effective but complex solution is charging each cell separately. This is not achievable in a free moving vehicle such as an aAGV. For this reason, all 8 cells in the proANT's battery are connected and leveled through a balancing circuit. A balancer board is connected to each battery cell. The balancer board monitors each cell's voltage and routes a balancing current to the least loaded cell. Each balancer board communicates to the Battery Management System (BMS), which itself communicates with the Fleet Management System and the charging points.

The proANT aAGV carries two charging contacts. The charging contacts use a low voltage level to communicate with the charging station. Only after a hardware handshake between charging station and aAGV is achieved, the full loading current is brought to the contacts of the charging station and routed to the aAGV's batteries.

3.2 Opportunity Charging

Batteries with Lithium-iron technology can be charged frequently and with high charging currents, without losing charging capacity or durability. Due to this, the aAGV can be charged spontaneously while in continuous operation.
For instance, a charging station can be integrated into the loadport of a production machine. While the aAGV is being loaded with transport material, it can connect to the charging station and fill its batteries for 10 to 300 seconds.
Implementing opportunity charging in the application can greatly reduce the time in which the aAGV is out of duty due to low battery status. Opportunity charging can also maintain the battery loading status between 30-70%, where the battery has its greatest longevity.

4 Software components

4.1 AGV Interface Controller (AIC)

The AGV Interface Controller (AIC) is a high-level software that can run on any of the costumer's servers.

The AIC is used to generate, coordinate and distribute aAGV transport requests. It can be interfaced to many devices such as sensors, barcode scanners, manual pushbuttons or touchpanels to automatically or manually generate transport requests. It can also be interfaced to common ERP or MES systems such as SAP or Oracle to automatically generate transport requests.

When transport requests are generated, the AIC evaluates the position and status of each vehicle in the fleet and routes the transport task to the idle robot that is closest to the transport's source.

Furthermore, the AIC monitors all vehicles' battery states and automatically generates and schedules loading requests.

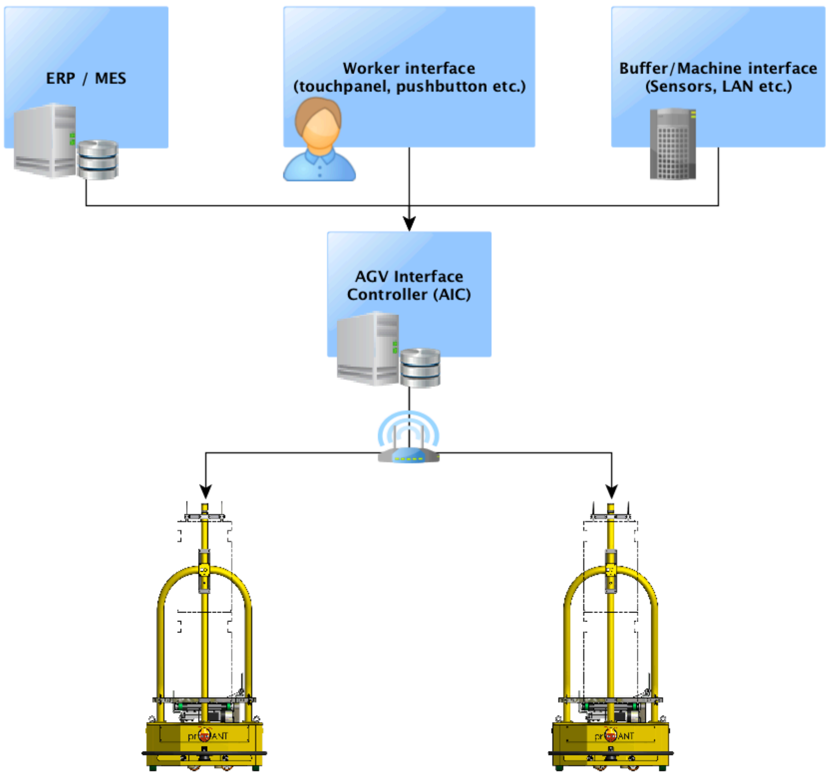

Figure 5:Transport information flow using AGV Interface Controller (AIC)

4.2 Fleet Management Software (FMS)

The Fleet Management Software (FMS) is a software that usually runs on the same server as the AIC.

The fleet management software is used to scan and manage the plant's map. Updates in the map (i.e. incorporating new transport sources or goals) can easily be made and downloaded to the entire fleet at once.

In addition, the FMS is used to service and incorporate single aAGVs in the fleet.

4.3 aAGV Core Software

The core software is located on each of the proANT aAGV's and represents its brain. Vital functions such as navigation and route planning are implemented in the core software.

The core software is based on the Robot Operating System (ROS), which is an open source framework for robot software development. Many companies and institutions such as universities are working and updating ROS functions, causing it to be a source of the newest advances in robot software.

4.4 Battery Management Software (BMS)

The proANT's Battery Management System is used to manage and monitor the battery of the aAGVs.

The BMS monitors the aAGV's battery cell voltages and notifies the AGV Interface Controller when the status is low. The AIC then schedules a break to charge the aAGV.

When charging, the BMS manages the charging current in order to balance the voltage state on all of the battery's cells. When this is done, no cell is stressed in excess and the total longevity of the battery is boosted.

The BMS can also be used to manually evaluate the battery cell's voltages while the aAGV is in action. This makes it possible to identify a fault on a single battery cell, thus making it possible to exchange only a single cell of the battery instead of the entire battery.

5 Examples of implemented load handling techniques

5.1 Roller conveyor

Figure 6: passive roller conveyor on proANT aAGV

An active roller conveyor is built upon the proANT. This enables a cost-efficient solution for loads that are pushed on and off the aAGV.

5.2 Belt conveyor with lift

A belt conveyor is built upon the proANT. This makes it possible to actively pick and drop the load onto static conveyors.

The belt conveyor can be lifted or lowered dynamically, enabling the aAGV to service stations with different loading heights.

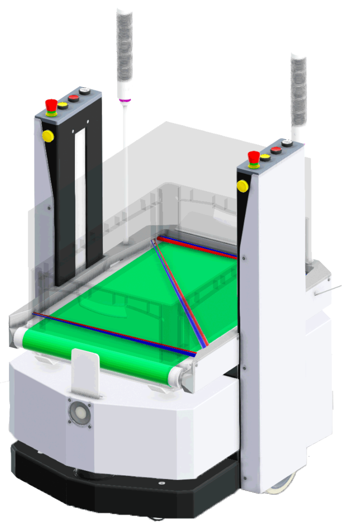

Figure 7: Active conveyor on proANT aAGV

5.3 Passive lift

Figure 8: Passive lift on proANT aAGV

Two runners are built upon the aAGV. These can be lifted or lowered dynamically.

This design enables to proANT to drop loads on and off passive working stations.

5.4 Customized

The three possibilities listed above are mere examples of applications. We usually adapt the proANT aAGVs to fit the costumer's individual needs.

Due to this, we have already implemented several further load handlings techniques for diverse applications such as the transportation of automobile tires or handling of stacked Boxes with a total payload of 200kg.

Figure 9: proANT with 200kg payload

For more information, please contact

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