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Automated outdoor goods transport system using precision autonomous transport vehicles

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Abstract:

This paper presents the completed PRO-ASSEM project on automated outdoor goods transport using precision autonomous vehicles. The work addressed the need to connect separate production and warehouse buildings by autonomous transport while accounting for uneven surfaces, changing environmental conditions and a limited number of localisation features. The scope of research and development is discussed, with particular attention to visual odometry and localisation using multiple information sources. The resulting product, the MODEL 3000 autonomous transport vehicle, is then presented. Its commercial specification states a payload capacity of 1200 kg, a travel speed of 1.2 m/s and an operating temperature range from −20 to +45°C. The paper also describes a transport management architecture comprising robots, transfer stations, exchange buffers and a Fleet Manager. It is a technical case study of a completed project; commercial product specifications are distinguished from the research programme.

Keywords: autonomous mobile robots, AMR, outdoor transport, visual odometry, localisation, fleet management

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1. Introduction

Material flow automation in industrial plants often covers production workstations and warehouses, while transport between buildings remains a task for vehicle operators. At sites with separate buildings, however, crossing a yard, ramp or internal road forms part of the same logistics process. An interruption in automation at the factory door complicates workstation supply and the exchange of load carriers.

PRO-ASSEM addressed this need through its completed project entitled “Automated outdoor goods transport system using precision autonomous transport vehicles”. The project received support under the Regional Operational Programme for the Małopolska Region for 2014–2020, Measure 1.2 and Sub-measure 1.2.1. Its outcome is a transport solution represented commercially by the MODEL 3000 product [1, 2].

The purpose of this paper is to explain the relationship between the research challenges, the resulting product and transport process organisation. Earlier PRO-ASSEM publications concentrated on the mechanical and safety aspects of mobile robots for intralogistics [3, 4]. This paper focuses on outdoor operation and on the connection between the vehicle and a supervisory system for executing transport requests.

2. Technological challenge and scope of research and development

The main project objective was to develop a solution for precision movement of a loaded platform across open space, including operation at sub-zero temperatures. In this environment, wheel rotation measurements alone do not fully describe actual vehicle motion, while the availability of distinctive environmental features can vary along the route. The project application therefore linked development of the mechanical platform with work on velocity and position estimation [1].

The programme included design and construction of a remotely controlled outdoor prototype, commissioning and implementation of autonomy, development of a vision-based velocity estimator under laboratory and simulated operating conditions, development of an estimator using other data sources, and integration of localisation systems. A separate part addressed preparation for implementing the R&D results in the company’s operations [1].

This division separates two complementary engineering tasks: the ability of the vehicle to physically negotiate a route and the ability of the control system to determine its motion reliably along that route. A suitable chassis does not replace localisation. Likewise, a precision navigation algorithm needs a platform that provides appropriate traction conditions and stable load support.

The research programme considered vibration, viewing geometry, surface texture and topography, image sampling frequency and exposure time. Stereo camera arrangements, observation of more distant surroundings, inertial data and structured light were also considered. These topics describe the research scope recorded in the project application; they do not establish that every investigated sensor is fitted as standard to the commercial vehicle [1, 2].

3. MODEL 3000 as the project outcome

The resulting product is the MODEL 3000 autonomous transport vehicle intended for outdoor use. Figure 1 shows the vehicle, and Table 1 presents its main specifications. The values are taken from the commercial product documentation [2].

The design combines a load platform with a chassis intended for operation beyond a level indoor floor. Its dimensions of 800 × 1650 mm and ground clearance of 70 mm are relevant when assessing

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routes between buildings and the geometry of transfer stations. Route assessment must also account for the dimensions of the transported carrier and the space required for manoeuvring.

An integrated lifting unit with a capacity of 1200 kg and a stroke of 50 mm serves appropriately prepared carriers. The short stroke links lifting to load collection and placement. Carrier geometry and support height are therefore part of the transfer station design.



Fig. 1. MODEL 3000 autonomous vehicle. Source: PRO-ASSEM [2]

Table 1. MODEL 3000 commercial specifications [2]

Parameter	Value
Intended use	Outdoor operation
Payload capacity	1200 kg
Travel speed	1.2 m/s
Operating time between charges	8 h
Operating temperature	−20 to +45°C
Width × length	800 × 1650 mm
Ground clearance	70 mm
Maximum gradient[1]	15%
Lifting unit	1200 kg; stroke 50 mm
Navigation and safety	Laser lidar scanners
Travel accuracy without distinctive landmarks	10 cm over 10 m

[1] The product documentation describes this as the maximum gradient of an unpaved surface

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4. Motion precision in open space

An important part of the project was supplementing conventional odometry with information independent of wheel rotation alone. The project application describes visual odometry based on optical flow measurements between consecutive images. Changes in the image can be analysed to estimate motion relative to an observed surface or the surroundings. Development of this approach was linked to investigation of the conditions under which image information remains useful for control [1].

The programme distinguished instantaneous error, associated with adjacent image samples, from accumulated error over a journey. This distinction is relevant to outdoor transport: stable local velocity estimates should be combined with information that limits position drift over a longer route. The programme therefore also addressed hybrid localisation using odometry, lidar data and GNSS satellite positioning [1].

The MODEL 3000 commercial specification states outdoor travel accuracy of 10 cm over a distance of 10 m without distinctive landmarks. This parameter refers to a specified distance and reference conditions. It does not establish docking accuracy, stopping repeatability or a constant error over a route of arbitrary length. The offer separately lists a maximum position and velocity error of 1%, without a detailed procedure for determining this value [2].

The stated gradient capability also needs careful interpretation. The 15% value in the offer is a percentage gradient, not an angle of 15 degrees. Application selection needs to relate it to travel direction, surface conditions, traction and the position of the load centre of gravity. The maximum values in the specification do not establish that they can all be used simultaneously in every operating configuration.

5. System architecture and mission execution

The solution extends beyond the vehicle itself. The architecture described in the offer connects AMRs, transfer stations, operator interfaces, exchange buffers and a supervisory Fleet Manager. Figure 2 presents the principal functional relationships. The number of robots and stations depends on the specific process [2].

A cycle begins when an operator requests a product using a physical or virtual button. The station interface forwards the request to the Fleet Manager, which checks product and robot availability. Once execution is confirmed, the Fleet Manager identifies the collection and delivery locations and sends the coordinates and mission details to the robot. Confirmation that the request has been accepted is returned to the operator.

The robot collects the product, transports it to the destination and exchanges the carriers using a buffer. The empty container is subsequently returned to a designated area, and the vehicle reports readiness for another task. A buffer allows a full and empty carrier to be exchanged close to the receiving station, reducing the need for an additional journey. The configuration described in the offer allocates a space of 1.5 × 2 m for this purpose [2].

The robots, station interfaces and Fleet Manager require network communication. The offered configuration assumes that the user provides a wireless network. The statement that lidar navigation does not require plant modifications should therefore be read in relation to vehicle guidance infrastructure. Implementation still requires communication coverage, prepared transfer stations and traffic organisation.

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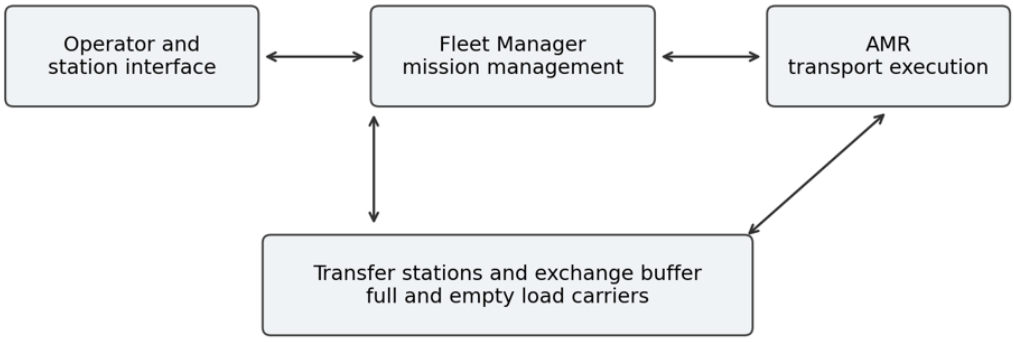

Fig. 2. Simplified functional system architecture. Arrows indicate information exchange or carrier handling, rather than network topology. Adapted from the system description in [2]

6. Plant integration and operational safety

The offer identifies laser lidar scanners as navigation and safety components and refers to PN-EN ISO 3691-4 [2]. The international ISO 3691-4:2023 standard addresses safety requirements and verification for driverless industrial trucks and their systems [5]. A list of sensors alone, however, does not define the conditions for safe operation of an entire application.

Implementation design needs to address transport routes, load transfer points and shared space with people and other vehicles. Motion settings and protective functions must be considered in relation to the actual load and operating environment. Speed, gradient and temperature specifications support equipment selection but do not replace assessment of a specific application.

Outdoor operation also requires defined conditions for route maintenance and cleanliness of sensing components. A temperature range of −20 to +45°C does not by itself establish suitability for arbitrary icing, precipitation or contamination. Likewise, the nominal operating time of 8 h needs to be related to the transport cycle, payload and usage pattern; the offer does not provide a detailed measurement procedure for this value [2].

7. Implementation significance and conclusions

The completed project expanded the PRO-ASSEM portfolio to include an autonomous outdoor transport system. Its significance lies in the combination of a load-carrying platform, localisation supporting route execution, and software coordinating deliveries. The product can therefore be considered part of material flow between facilities rather than solely an individual transport vehicle.

The project application identified potential uses among manufacturers of building materials, pallets, furniture and large products, as well as plants using outdoor storage areas [1]. Suitability for a particular user depends on repeatable transport requests, carrier geometry, route conditions, and the ability to arrange transfer points and communication coverage.

The resulting MODEL 3000 has a stated payload capacity of 1200 kg and is complemented by an architecture for managing missions and station interfaces. The technical value of the project lies in treating mobility, motion precision and transport organisation as connected engineering tasks. The parameters presented describe the commercial specification. Quantitative assessment of throughput,

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technical availability and economic performance of an individual implementation requires data from its actual operating cycles.

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