Smart Air Cargo Trailer - Autonomous air cargo ground transportation in a mixed traffic environment (SAT)

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Abstract. The Smart Air Cargo Trailer (SAT) project aims to transport air freight shipments autonomously and according to demand between the freight forwarder and the air freight handler by automating short-haul transports between air cargo handlers and forwarding agents using a cloud-based platform and replacing conventional trucks with automated guided vehicles. The envisioned solution leads to demand-oriented transports, which are carried out, when necessary, on the part of either the shipper or the recipient (variable push-pull control). The self-control algorithm must be able to represent several triggering / decision situations. With the help of camera-supported barcode reading, information about the loaded packages can be captured without interrupting or disturbing the process, thus considerably simplifying the process of outbound scanning. Packages are recognized parallelly and not individually from a video stream and the attached barcodes are read. A special challenge is the recognition of the different packages, the recognition of partially covered barcodes and the handling of different lighting situations. The project identified the necessary requirements for autonomous driving in a mixed traffic environment and evaluated their feasibility according to the current state of the art.

1 Background

The physical exchange of shipments between freight forwarders and airline air cargo handling facilities is currently handled by conventional road transport. Even though distances in the air cargo areas of airports are often less than three kilometres, the process of delivery and drop-off often takes hours, with only a few minutes of driving time. One reason for the long waiting times is that current processes are push-driven. As the organizer of the individual airfreight shipments, the freight forwarder is responsible for on-time delivery. Deliveries after the so-called "Latest Acceptance Time" (LAT), it will not be transported on the booked flight. In order to minimize this risk, shipments are delivered unnecessarily early to the air cargo handling facilities. At the same time, handlers lack transparency as to which booked shipments are delivered by the freight forwarder when or at all, making it difficult to plan the warehouse staff for handling the delivering trucks accordingly. Therefore, only handling in the order of appearance is possible. As a result, there are delays and waiting times for delivery. These waiting times cause forwarders to refrain from consolidating consignments in truck transports and thus often only operate trucks with very low capacity utilization so that at least some of the consignments are dispatched on time. These unbundled transports place an additional burden on the traffic system and the dispatching.

In 2017, these circumstances led to waiting times of up to 10 hours in the peak freight season, before the air freight handlers could unload at the truck ramps.

In addition, this problem is aggravated by the shortage of skilled truck drivers. Fully autonomous trucking is therefore a possibility to alleviate this problem and at the same time make the processes more efficient.

2 Objectives

The goals of this research project were to define the possible requirements for a fully autonomous acting vehicle in a mixed traffic environment.

At the same time, a cloud-based monitoring and control mechanism has been developed, which allows the automated vehicle to be controlled based on the current loading status, thus allowing the transformation of the current push-process into a transparent pull-process.

The project answers the question whether the current state of the art already allows the operation of an autonomous vehicle in a mixed traffic environment and which changes in current air freight processes and air freight security requirements are necessary to achieve this in order to simultaneously enable increased process transparency and thus efficiency.

With a cross-actor approach and a consistent digitalization of processes, the prerequisites for demand-driven, autonomous transports are created.

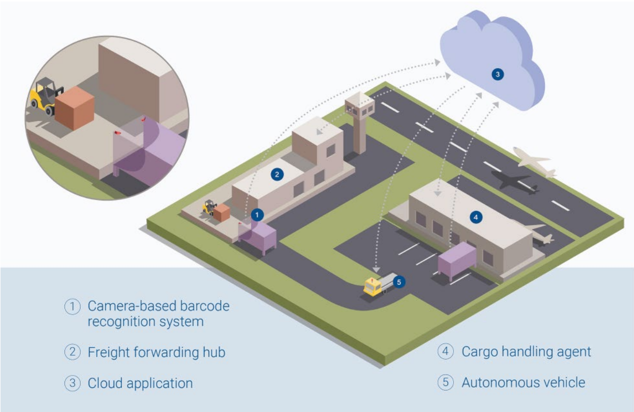

Figure 1 - Project environment and framework parameters

Process-economic goals of the project were:

- Increased transport efficiency and capacity utilization
- Reduction of total process times
- Reduction of waiting times
- Reduction of the error rate at the interface between handling agent and forwarder
- Reduction of personnel-intensive peak loads on the players

Technical goals were:

- Development of a robust system for automatic recognition of barcodes of goods on moving pallets
- Development of algorithms for barcode recognition by multicamera data fusion and for the solution of masking problems
- Development of a self-control algorithm based on a multidimensional decision matrix and multiple input data
- Establishment of a cross-activity platform that checks the plausibility of the recorded data and takes over the (self-)control of the transports
- Adaptation of a standardized transport container (swap body) as well as the mechanical interfaces to ensure automatic pickup/delivery by a shuttle vehicle
- Solutions for implementation of autonomous transports in an environment with mixed traffic

3 Approach

Baseline for this research project was the assessment of the current status of the air cargo processes and the technology used. Based on the identified inefficiencies an optimized process was then developed. Primary focus of this process development was the implementation of a variable push-pull-process.

The process design was then programmed in a cloud software solution which acts as an information hub. Simultaneously to the process development a multi-camera system was designed to enable reliable multiple barcode reading of moving objects.

The theoretical designs were firstly tested in laboratory conditions. A small-scale demonstrator was built to show the concept at various trade fairs and aviation conferences to get valuable user feedback.

In 2019, a first set of trials took place with a conventional truck and a swap-body in the CargoCity South of Frankfurt airport under real life conditions. One year later, a full integration test with an autonomous truck was successfully completed.

4 Results

The technical components were tested and validated in two test runs. The achievement of the process-economic goals can be proven conceptually. A quantitative verification would require extensive tests with real freight, which are currently not feasible due to the existing legal restrictions.

The key results are:

- Development of a camera-based barcode recognition system that reliably identifies several shipments simultaneously during loading and unloading. The recognition rate was above 93%. Time-consuming scanning processes can be omitted and at the same time on-time and error-free loading can be ensured.

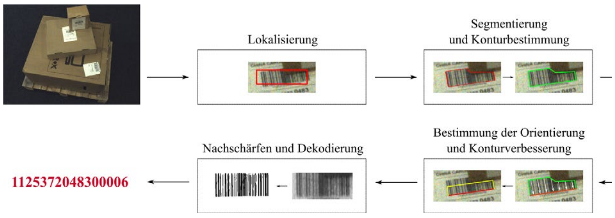

Figure 2 - Schematic overview of the image processing workflow

- Programming of a cloud platform for information transfer or data sharing between the participants in the air freight transport chain. The platform receives the data from the camera system and controls the transports using multi-criteria logic. These can thus be carried out as required and on time.

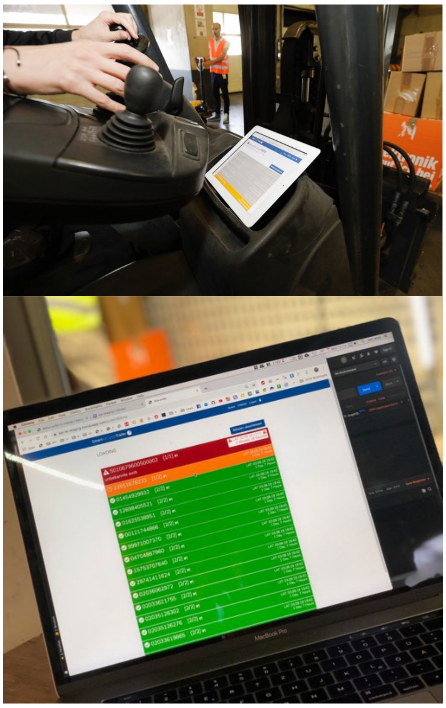

Figure 3 - Web front-end of the cloud platform (top: tablet based for the floor operation; bottom: computer based for the dispatcher)

- Definition of requirements for autonomous or automated air cargo redirection transports, handling and transport processes

Overall, it has been shown that the development status of autonomous driving still needs to be massively improved until regular operation with autonomous or partially automated vehicles will be possible.

The following aspects were identified as main challenges for the autonomous driving in a mixed traffic environment:

Legal:

- Liability and insurance of damages to freight and third parties
- Air cargo security regulations as these require the checking of an ID document (of the driver) as part of the export delivery process

Technical:

- Integration of automated vehicles into the traffic
- Turning operations
- Overtaking and lane change manoeuvres

The main technical challenges occurdue to the recognition and prediction of the behaviour of other road users by the on-board sensor technology.

As the project progressed, the following additional successes and findings have resulted from the further development of the project approach:

- The existing physical documentation exchange between forwarder and handler can already be incorporated into the digital information flow. With the elimination of the physical AWB transmission, the driver is removed as far as possible as a process participant in document-based air cargo handling.
- The use of an electric truck significantly reduces emissions (when using renewable energy sources). Due to the low gradients and short distances, an electric truck is suitable for this purpose.
- In a first test, the feasibility and viability of the concept was demonstrated with a conventional truck. This means that these components can be launched on the market without having to wait for the market-ready implementation of autonomous driving. Consequently, the initial investment is reduced and enables a step-by-step implementation. Furthermore, this will have lower effects on the actual number of jobs.

The validity of the results for the camera system and the cloud platform can be confirmed by the two test series conducted. The driving tests demonstrated the basic feasibility of autonomous driving but also reflected the need for further technological development. V2V-, respectively V2I-communication can be a necessary supplement to the on-board sensors.