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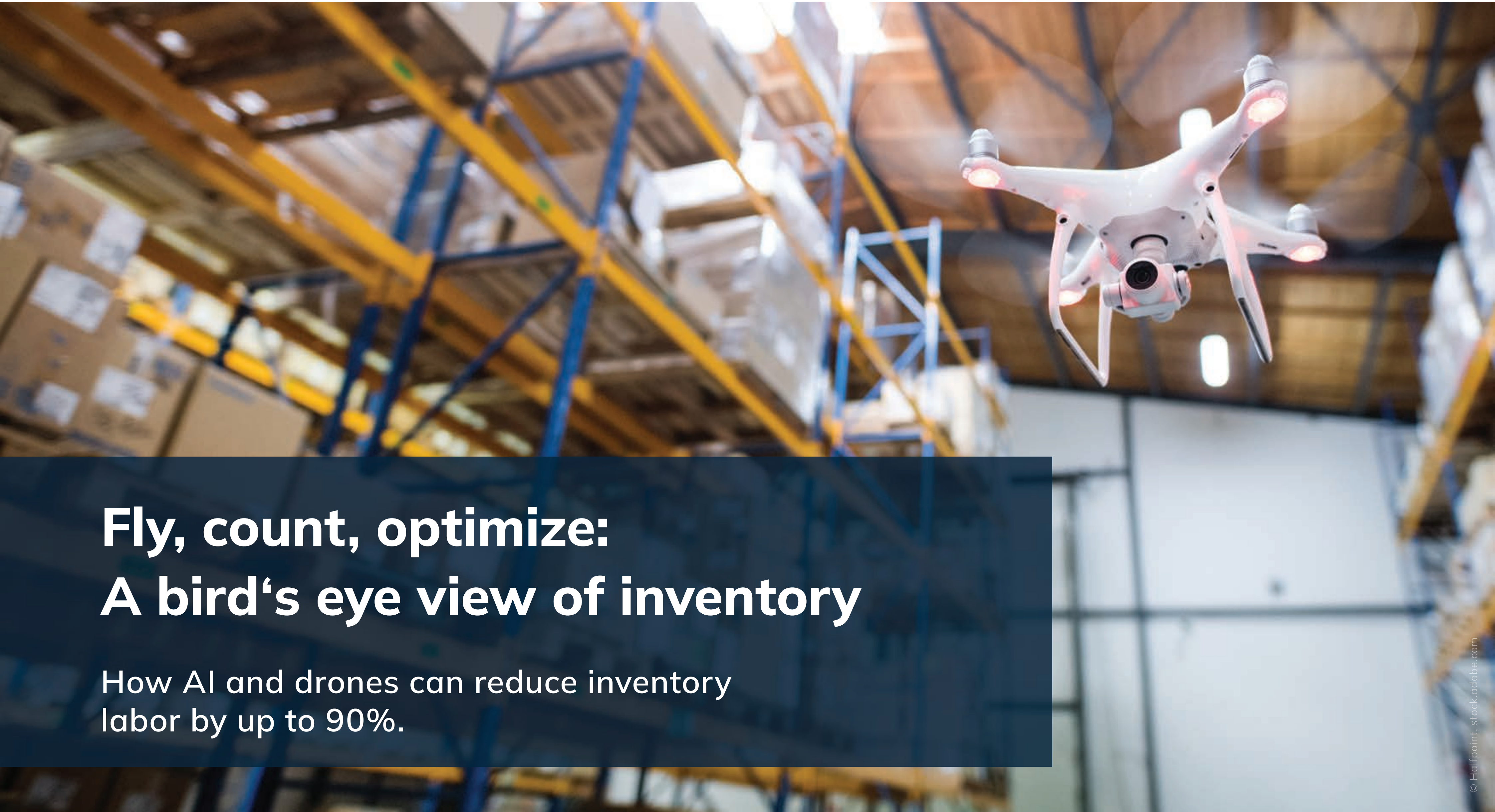

Fly, count, optimize: A bird‘s eye view of inventory

How AI and drones can reduce inventory labor by up to 90%.

This white paper is about our approach to inventory automation. We will show you how various AI processes can be used to eliminate manual counting while increasing the visibility and traceability of an inventory.

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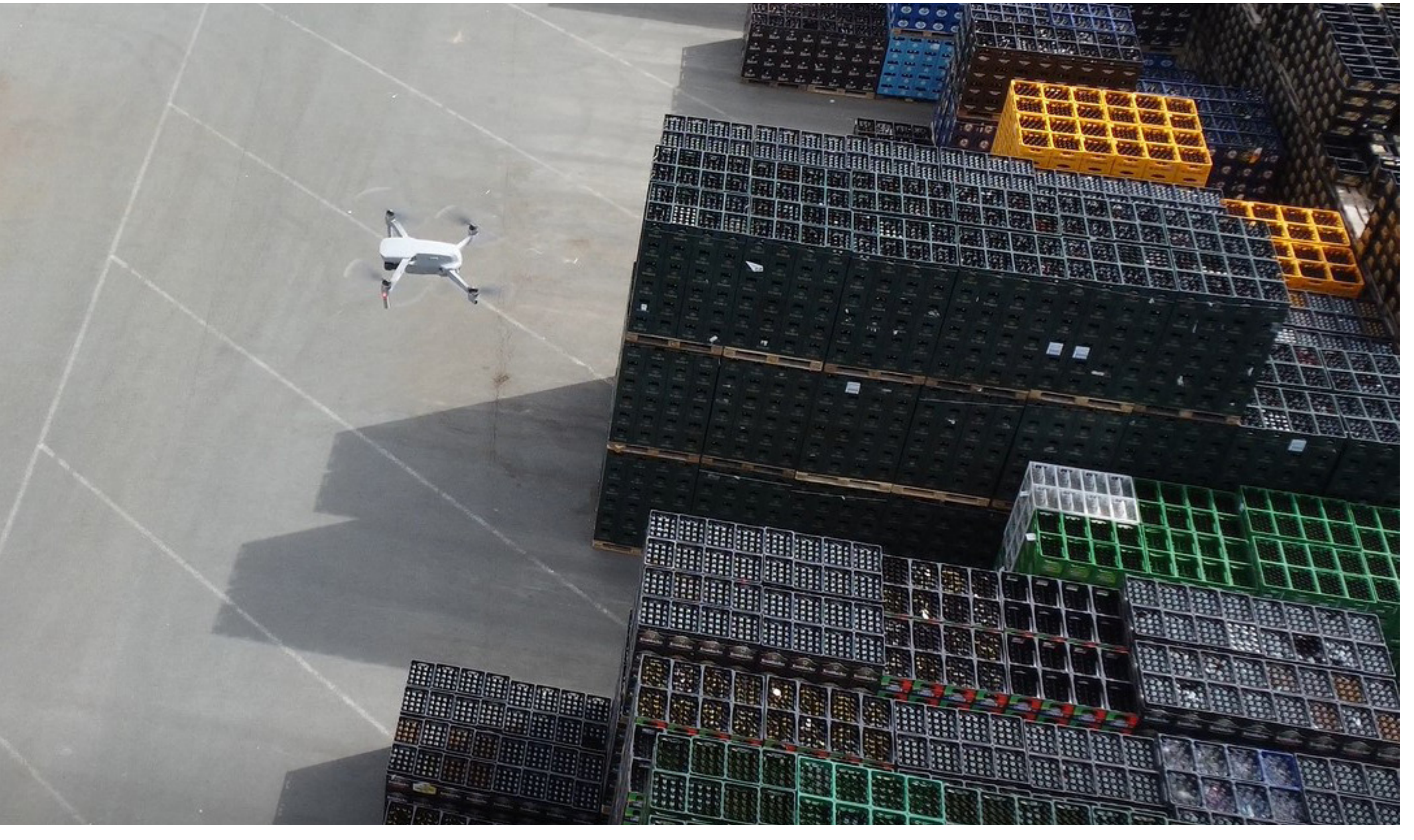
Stock inventory

Taking inventory is often a manual process that requires a lot of human resources to count physical goods and disrupts the regular flow of day-to-day business. The problem is that inventory is required by law (§240 HGB) and must be taken at least once a year. At the same time, inventory can also be a tool for controlling internal processes and ensuring transparency within the company. For example, stock shortages can be identified and their causes investigated to rule out process deviations or other irregularities.



Inventory can be particularly useful in companies with a high volume of goods movements.
When conducting an inventory or stocktaking, companies are basically faced with a conflict between effort and benefit. This is one reason why, in practice, companies often use spot checks or partial inventories during the year, in which only a certain part of the inventory is counted. Another option, which is easier for users, is to automate the inventory process, i.e., to record the current inventory without manual counting by a human. There are several ways to do this. Two main approaches have become established

Locating and identifying products using sensors

When products are equipped with sensors, they can be read from their environment (e.g. warehouse).
In practice, RFID tags are often used to track products or load carriers.

However, especially when these products are difficult to access, e.g. when they are stored on high shelves, there are approaches to use drones equipped with an RFID reader that can read RFID tags of products and load carriers at close range. This approach is basically functional and offers some advantages, but is not applicable to all types of products. Typically, products and load carriers are not tagged, and in many cases the cost of obtaining and applying the tags would outweigh the benefits.

Another approach to identifying products and carriers is to read product labels such as barcodes or QR codes. However, this requires that labels are always present and can be read, for example, by a drone with a camera. In principle, this is a solution with great potential and rapid success. Unfortunately, not all products are equipped with labels, or it is not possible to use them in a meaningful way.

In general, it can be said that AI-based image processing has enormous potential, especially in logistics, but that this potential has hardly been realized in the case of inventory. In our project, which we conducted together with our partners Getränke Essmann and Diephaus Betonwerk, we not only solved the problem of manual counting in a prototypical way, but also tried to exploit this potential by combining drones and AI.

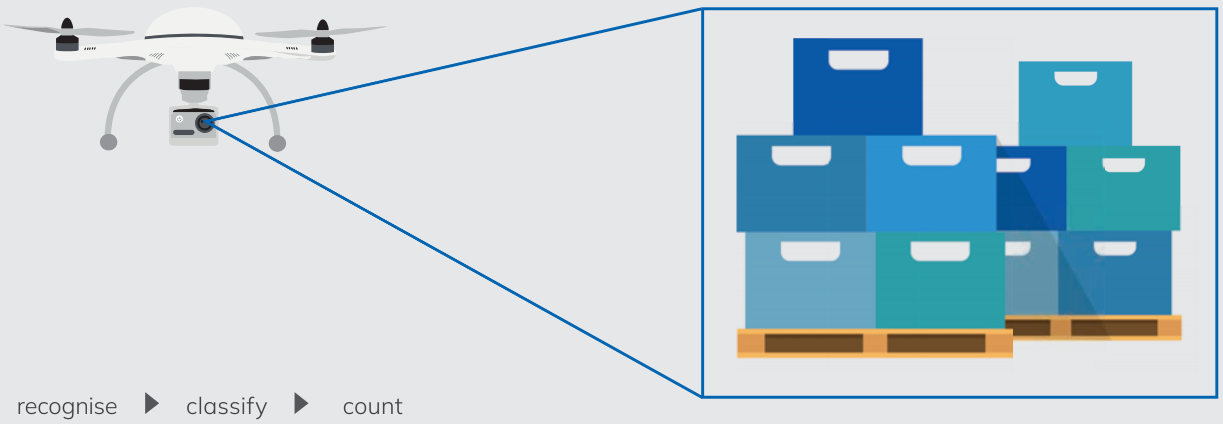
How AI-assisted inventory works

Our inventory automation is based on approaches that process a visual representation of the product to recognize, classify, and ultimately count products:

Recognition: The first step is to recognize the products on an image of the warehouse. A distinction is made between a frontal view and a bird's eye view. Both perspectives are processed, otherwise a complete counting of the pallet stacks is not possible.

Classification: Once products have been identified on an image, they must be classified to determine which product has been identified from the inventory. This is necessary to obtain a value for the inventory.

Counting: Finally, the detected and classified products are counted. Both perspectives are taken into account and the results are linked.

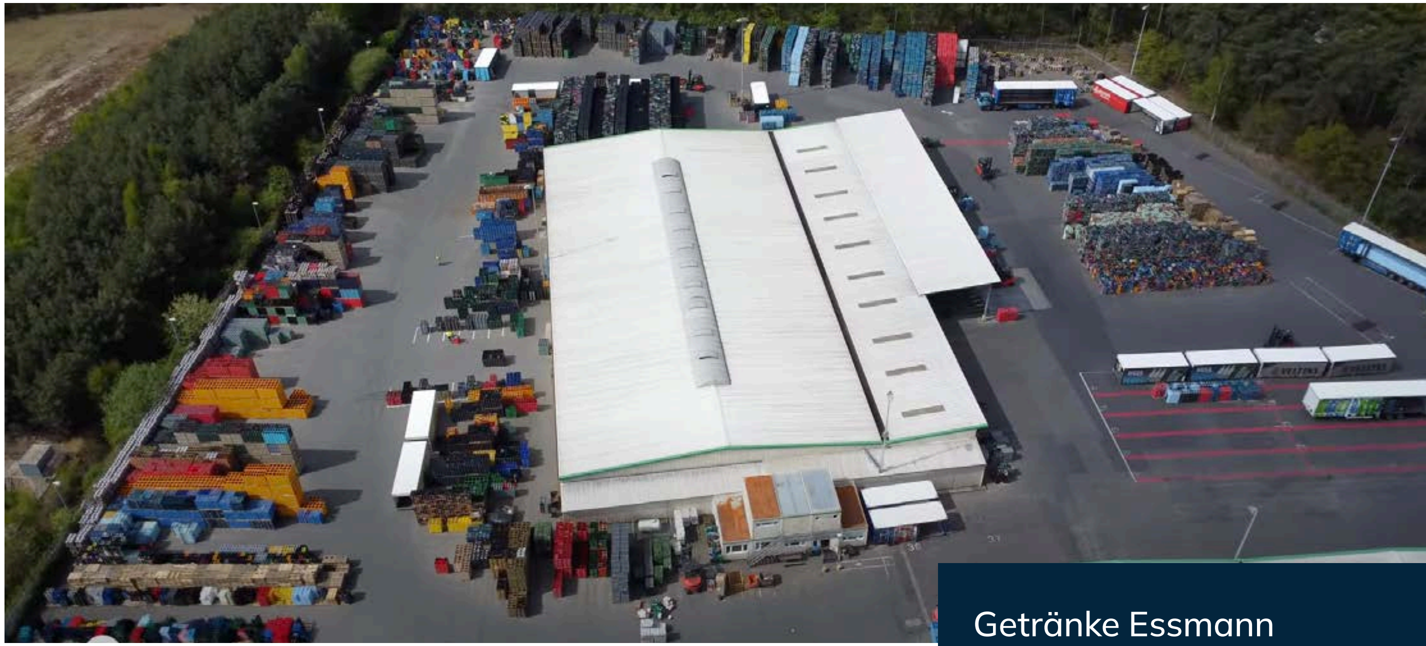


Our joint implementation with Getränke Essmann and Diephaus Betonwerk

As part of our collaboration with Getränke Essmann and Diephaus Betonwerk, we set out to optimize the inventory process and completely eliminate manual counting.

Our two partner companies have in common that many products are stored in blocks in the external warehouse. This was our first focus during the implementation. In both companies, inventory was done manually by forming several teams of two to three people to walk through the warehouse and record the products. The number of pallets and the product found are recorded. However, the structure of the warehouse is different: While at Getränke Essmann the entire warehouse is counted during the inventory, at Diephaus Betonwerk all storage bins are geocoded and the inventory is counted bin by bin.

The counting process at both companies provided the framework for the development project. The goal was to implement a solution that could capture inventory with human-like accuracy while eliminating manual counting activities.
A combination of drones and AI algorithms for object recognition was used. The prototypical implementation is done in several steps. First, the objects (pallets) on the images have to be detected, then the detected objects have to be localized, and finally they have to be classified in order to assign a value to the pallets. In the first step, we focused on the front view of the and later extended the approach to the top view.



Getränke Essmann

Diephaus Betonwerk

Functional architecture of the inventory solution

The implementation of our inventory approach begins with the creation of a comprehensive database. This is done by capturing both front and top view drone footage under the most realistic conditions possible. This comprehensive data collection forms the basis for training and optimizing the AI models.

The collected images must first be pre-processed. This includes, for example, cropping the images or annotating, i.e. marking and categorizing relevant objects or features in the images. This preprocessing phase is crucial to effectively train the AI models.

The training is based on a pre-trained state-of-the-art AI model for object recognition.
This model is further optimized with customer-specific data, a process also known as fine-tuning. The choice of AI architecture and training parameters depends on the use case of the user company.

Based on the trained model, different image enhancement methods can be evaluated. These can be classic methods such as image rotation or scaling, or methods that simulate realistic conditions such as drone behavior or weather effects.

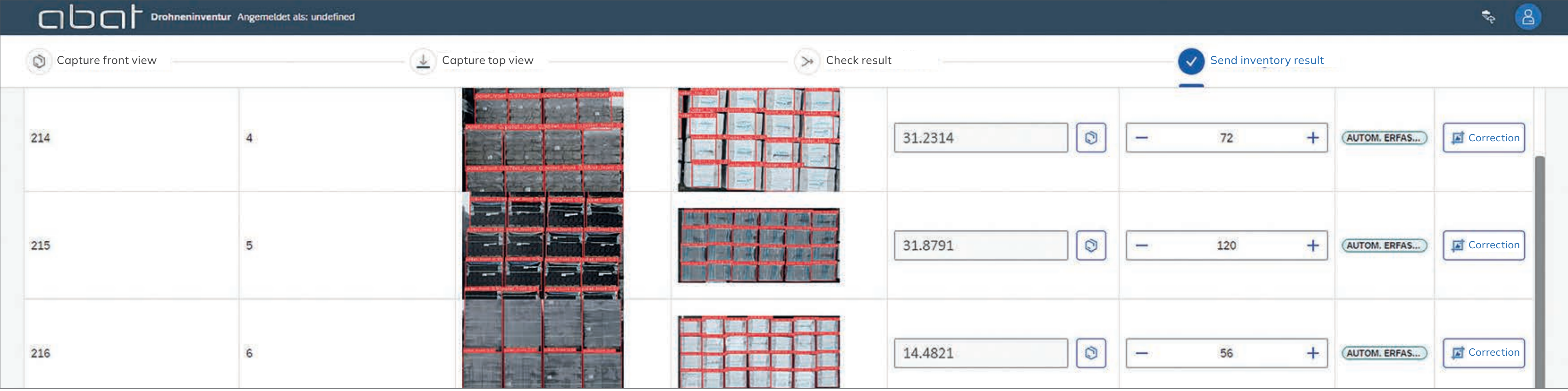
These can include contrast changes or perspective transformations. Image enhancement can be used to make the models more robust, and at the same time a smaller database is needed to achieve high performance.

Train separate models for different views

Separate models are trained for the front view and the bird's eye view. These separate models are then linked together. When processing the frontal perspective, the implemented inventory application logic is used, for example, to detect missing objects in the first row of storage bins and to validate the object detection results.

In addition to the object recognition, a classification of the products is also performed. This can be done either by using product identifiers such as barcodes, QR codes or OCR, or by classifying objects based on optical characteristics.

By linking the top and front views, the results of the different AI models can be combined and aggregated into a single inventory result.
This provides a detailed, accurate and comprehensive view of the inventory that goes far beyond what is possible with traditional methods.



Inventory implementation and SAP integration

All of our AI components can be used as individual services that can be accessed through unified interfaces to analyze product or warehouse images. In addition, a web application is available for inventory control. Inventory documents can be loaded and displayed from the SAP system.

Depending on the specific storage conditions, the drone images of the storage bins to be captured can be generated in different ways.

This allows a flexible and customized adaptation of the methodology to the respective circumstances and requirements.

1. Manual routes: One option is to define manual routes, where specific routes are flown manually. This can be useful in complex warehouse environments or for special imaging requirements.

2. Fixed and repeatable routes: Alternatively, fixed routes can be defined and programmed to be automatically flown by the drone. This ensures consistent and repeatable coverage of the warehouse area. Once defined and successfully flown, these routes can be repeated for future inventories.

3. Dynamic flight routes based on geo-coordinates: If geocoded bins are available, flight routes can also be dynamically created based on these geocoordinates. This allows for very precise and targeted coverage of specific bins and is an efficient way to inventory individual bins when a full inventory is not required.

Although the use of drones is an efficient and flexible method of taking inventory, there may be situations where other techniques are more beneficial. For example, fixed cameras or cameras on other forklifts can be used to generate the necessary images. By combining technologies in this way, maximum flexibility and efficiency in inventory capture can be achieved.

After uploading the images from the warehouse to an inventory document, automatic analysis of the images can be started and, if necessary, checked and verified upon completion.

Once the count is complete, the inventory documents can be transferred back into the system. In addition to controlling the inventory, the implemented application also allows for complete documentation of the inventory with images of the warehouse at the time of the inventory, which also simplifies the traceability of the results.

Potential and applications

In summary, it has been shown that manual counting during an inventory can be largely automated using drones and AI algorithms.
Our experiments and tests have shown that the resulting models are able to detect products with high reliability. Instead of having multiple teams manually counting, this approach would require only one person as a drone operator to take images of the warehouse. The actual counting would be done by the AI models. When we compare the status quo of manual inventory with automated inventory using measurable metrics, the potential of the solution becomes particularly clear. If you compare the labor required to prepare, perform and follow up on an inventory, the use of a drone in combination with our AI models can save up to 90% of the labor.

The biggest savings come from automating the counting process: Instead of manually recording goods or products, the drone can (partially) autonomously fly through the warehouse, take photos and videos, and then automatically analyze the resulting images without manual effort. As a result, only about 5% of the time previously required is needed. Another big advantage is the documentation of the analysis and the captured images (with time stamp). This means that at any time it is possible to see what the condition of the warehouse was at the time of the inventory - in principle, this ensures complete and improved documentation and, in addition, any necessary recounts can be carried out directly in the application.

Our results so far clearly show that automated inventory using drones and AI is transferable to different warehouse situations. Our solution is not limited to external block warehouses - by adapting our components, other warehouse and product characteristics can also be mapped. In addition to supporting different types of warehouses, the modular structure of the approach also enables the connection of different systems (both SAP and non-SAP).

The next evolutionary step: From 2D to 3D analysis with photogrammetry

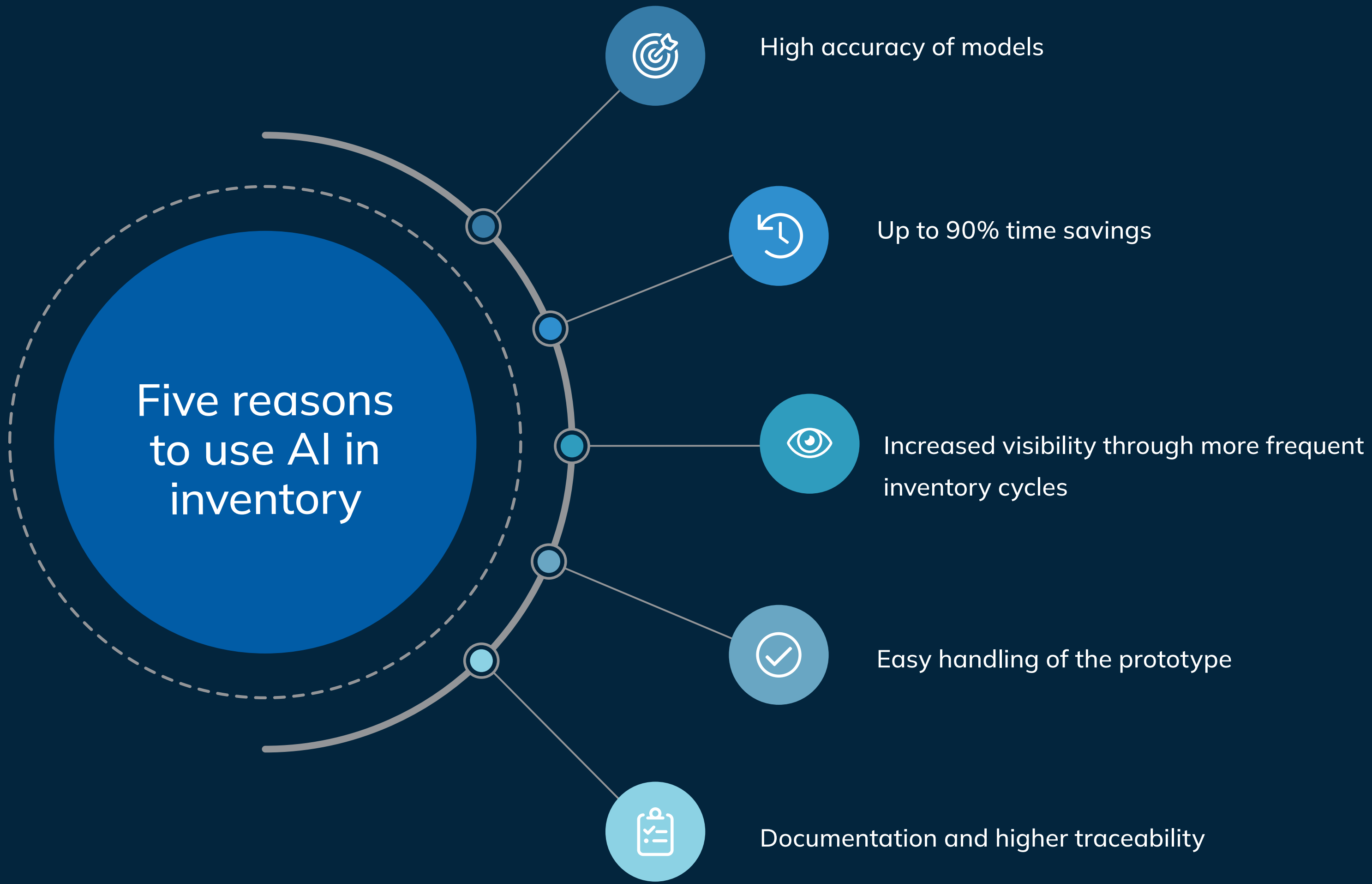
So far, our inventory approach has focused primarily on 2D imagery. While two-dimensional images are a rich source of information for machine learning and artificial intelligence, they are limited in the complexity of their spatial representation. While they can easily provide important information such as size, position, and identification of objects, they have difficulty adequately representing spatial relationships and depth.

To overcome this limitation, the approach has been further developed. Photogrammetry, a technique that computes 3D models from multiple 2D images, was used to move into the third dimension.
By calculating 3D models from 2D images, more detailed and comprehensive analyses can now be performed. Common features in the different images are identified and their position relative to the camera is calculated. This information can be used to create a 3D model of, for example, a warehouse.

A major advantage of 3D photogrammetry is the ability to link geocoded point clouds to 2D images. This linkage allows for an accurate and detailed representation of the real world in three dimensions. Geocoded point clouds consist of millions of points, each containing a position in space and often color information. Combining them with colored 2D images creates an accurate 3D representation of the scene that can be used for a variety of applications.

In addition to detecting and identifying objects, the 3D approach also opens up the possibility of detecting, locating, and measuring bulk materials. Until now, measuring bulk materials has been a difficult and often inaccurate task because their irregular shape and unpredictable distribution make accurate volume determination difficult. With 3D photogrammetry, it is now possible to create detailed 3D models of bulk materials that allow accurate volume calculations. Rough estimates are a thing of the past.

It is also possible to integrate the 3D approach into existing systems and applications. The 3D approach is linked to existing processes and tools to enable a seamless transition and optimization of existing workflows. Of particular note is the connection to SAP EWM and WM, which enables deep integration with existing warehouse management and material flow systems. Overall, the 3D approach provides a true evolution and optimization of the existing solution.


Five reasons to use AI in inventory
High accuracy of models
Up to 90% time savings
Increased visibility through more frequent inventory cycles
Easy handling of the prototype
Documentation and higher traceability

Reference to publications

Under the title „Using Camera-Drones and Artificial Intelligence to Automate Warehouse Inventory“ we presented our project at the international AI symposium „AAAI 2021 Spring Symposium on Combining Machine Learning and Knowledge Engineering“. The paper of René Kessler, Christian Melching, Ralph Göhrs and Jorge Marx Gómez can be found at:
https://proceedings.aaai-make.info/AAAI-MAKE-PROCEEDINGS-2021/paper38.pdf

In addition, our approach can also be found in the „Praxishandbuch digitale Automobillogistik“ in a book chapter written by René Kessler, Markus Fischer and Stefan Rosenwald entitled „DroSmarte Inventurprozesse - Wie durch den Einsatz von KI und Drohnen Prozesse optimiert werden können“.
Link:
https://www.springerprofessional.de/drosmarte-inventurprozesse-wie-durch-den-einsatz-von-ki-und-droh/25292442

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