Paper ID #

Process optimisation in the empty container depot with the help of artificial intelligence: Project Cookie

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Abstract
The aim of the IHATEC project "Cookie", which is funded by the German Economics and Transport Ministry (BMWV), is the optimisation of processes in the empty container depot with the help of artificial intelligence. The first step is the development of AI-based image recognition that identifies and assesses UCIRC (Unified Container Inspection and Repair Criteria) relevant damages. The project name COOKIE stands for "COntainerdienstleistungen Optimiert durch Künstliche IntelligEnz". In English: Container Services Optimised Through Artificial Intelligence.

Keywords:
Shipping Container, Container Shortage, Container Fleet Utilization, Container M&R, Artificial Intelligence, Container Depot, UCIRC Inspection, IICL,

Background

Global demand for empty containers far exceeds their supply. There are continuous bottlenecks in the provision of empty containers, because the containers have to be checked for damage to ensure they are in proper condition before they can be used again for cargo. The reliable identification, assessment and its subsequent repair of damages according the relevant industry criteria's **UCIRC and CSC (Convention for Safe Containers)** for empty containers as part of the M&R process is a vital contribution to meeting the global standard set by Container Owners and the IMO (International

Maritime Organization). Until now, checking the condition of containers has been largely a manual operation carried out by container inspectors, who are highly qualified professionals.

In a multi-year process, the industry has agreed to apply universally accepted standards in this area. These include inspection criteria for the assessment of damages (UCIRC & RCIRC and IICL6) as well as the CEDEX damage code structure for documenting the extent of the damage. The CEDEX code was drawn up as 1985-87 ISO TC104 and first published in 1989 as ISO 9897. This is the standard used worldwide for recording damages to freight containers, with fixed data values:

- Location Coordinates (4 digits)
- Component Component description (3 digits)
- Damage Damage description (2 digits)
- Repair Repair work (2 digits)

As mentioned above, damage identification currently comprises a series of manual operations, which are only partly IT-supported. None the less one very important digitized element is the inspection with a ruggedized handheld device (Zebra TC72) which is used to record the damage – both with pictures and further enriched with the CEDEX coding.
However every contain result in high potential for errors, while laborious process steps make the whole operation unnecessarily long-winded.

HCCR with the cooperation of Survey Compass (SC) are developing a **M&R Solution "SM&RT"** as a first step towards an end-to-end digitalisation of the whole M&R process involving all necessary functionality and data-exchange-patterns for all involved parties:

- Container Owners (Shipping Lines, Leasing Companies, Forwarders)
- Container Depots
- Inspection Companies
- Insurance Companies
- Machinery Manufacturers

At present, the "inspection module" of the SM&RT software is used to take between three and twenty photos of the container's condition in the course of the checking process and to allocate any relevant UCIRC/CSC damage using the CEDEX codes. There are in average 3-5 damages per container along with the earlier mentioned three to twenty pictures.
The subsequent process stage includes making a repair recommendation via a cost estimate and forwarding it, along with the pictures of the damages, to the client for approval.
In the current process, highly qualified "Container Inspectors" from HCCR photograph the relevant areas with a modern ruggedized handheld device (ZEBRA TC77) and enter the CEDEX damage codes into an Android based App which has been designed and intensively optimized in accordance with the physical process of container inspection. The result of the inspection – a "Ceck Report" is then sent to

SC-Flow cloud platform, which automatically calculates the estimated costs for the pending repairs.

The work order (for the repair) is then sent to a technician's (welder) handheld device. After the damages have been repaired and the overall work at the container has been carried out, the proper completion of the repairs is documented by taking photos which are allocated 1:1 to the photos of the original damage so that the client has access to a fully transparent record of the costs and quality of the work at any time.

Problem and objectives

Even so the check process is digital handheld supported – it still requires the manual recording and assessment of the container and to further it requires the highly qualified and experienced inspectors to differentiate in-between a damage vs. a "none-damage". "Container Inspectors" belong to the workforce who are not available in sufficient quantities, particularly at "Hinterland" terminals situated in areas of distinct economic activity, but also at maritime ports.
Hence, if it is case that the amount of returned containers is higher than the inspection capacity of the qualified inspectors it will lead to delays and creates a landside disruption due to the insufficient provision of containers. At the same time, the damage assessment depends to a large extent on the individual skills and abilities of the inspectors, which makes an objective comparison of the results more difficult.

Consequently, it is difficult to plan how long individual container inspections will take, so there is no basis for a reliable forecast of when the container will be repaired and therefore available. This uncertainty about the time at which the empty container can be re-used results in preventable stockpiling and excessive repositioning of empty containers, with negative financial and environmental consequences.

A long-term aim is to provide shipping lines and container leasing companies with a full transparency of the status of its equipment within the empty container depot, enabling to plan the re-use of empty containers through a further digitalisation of the inspection and repair processes. This will not only save time but also helps to reduce the unnecessary amount of handlings which are performed for inspections, especially for inspections with the result that the container does not have any relevant UCIRC/CSC damages.
By digitalising the process of gathering the container damage related data in a targeted manner, the COOKIE project is intended to contribute to this overall objective by making empty container depots an integral part of port logistics and linking them more effectively with other transport partners. This will not only increase planning and visibility for everyone involved, but also contributes indirectly to reducing traffic flows by optimising incoming and outgoing container exchange.

Potential solutions and their expected impact

With this logistical bottle-neck in mind, the research project COOKIE aimed to develop an AI-based image recognition capable of identifying and assessing UCIRC/CSC damages, which is beyond comparable projects which are "only" focusing on container damages in general without taking neither UCIRC/CSC into account nor enabling the AI to learn and x-reflect from the handheld based "Damage Picture – CEDEX Combination".
Explicitly the attempted AI learning progress via:

- OCR Gate Pictures
- Handheld Pictures directly interlinked with CEDEX Coding
- UCIRC/CSC Inspection Criteria

is the outline for a best possible result of the COOKIE project and is to this extent unique.
The Fraunhofer Center for Maritime Logistics in Hamburg-Harburg is the research partner for this project. It is developing an adaptive algorithm for image recognition processes, that is recognized, as a form of artificial intelligence (AI). AI-based image recognition, assisted by machine learning methods (especially "deep learning"), is intended to provide automatic support for the container check process via the identification of damages while:
- the container is passing the OCR-Gates at the entrance to the terminal/depot
- the inspectors at the terminal/depot during their process to identify and assess damages

The major aim is that the AI should be capable of detecting and assessing the "intact" status of a container reliably. This means that the project does not purely aim to automatically create an estimate of damages, but rather identify that the container has no damages of relevance and can therefore be treated as "intact". If this can be achieved a solid percentage of containers does not need to undergo a physical check by a inspector.

This standardisation and AI-digitization of the gate check via OCR would also make it possible to increase the efficiency of the whole container check process, including any subsequent repairs to empty containers and their return to the usable fleet.
The repair process is also to be optimised on the basis of digital data by comparing digital post repair photos with standardised repair criteria to determine the sufficiency of the repair quality.
If AI-based damage identification can successfully be integrated into terminal operations at the end of the project, the expectation is that this will reduce error rates, increase the uniformity of UCIRC/CSC damage assessment, speed up the process and boost overall process efficiency in the empty container depot.

Altogether, "COOKIE" is intended to boost the efficiency of empty container services. By building on the results of applied research in the COOKIE project and putting them into practice, we can make a

contribution to “just-in-time” logistics along the maritime container transport chain. At the same time, this will help to make the best use of scarce storage space in the port.

Efficient empty container services in turn result in savings and improvements for all the parties involved in the maritime freight handling process. Making it easier to plan the time at which an empty container can be used is to the benefit of many different players, including freight forwarders, loading, shipping and container leasing companies.

In addition, automated damage identification contributes to overcoming the bottleneck caused by the insufficient availability of highly qualified inspectors. Companies involved in container transport will also benefit from cost reductions if the initial damage assessment can be performed with less involvement from highly qualified professionals.

Project design and procedures

The research project COOKIE works with AI models for image-based damage identification. To determine which data must be collected and the precise locations at which data can be gathered for artificial intelligence, the first step was to document the current container inspection processes. Working from this basis, efficient target processes were defined and modelled. The results of recording and analysing current processes as part of the specification analysis help to define problems that were already known and also to identify and document any additional problem areas that were previously unknown. Where this is the case, direct interim measures can be taken, e.g. to make depot yard processes more efficient and increase employee awareness of the need for a careful use of resources.

Automated damage identification using images of containers is part of the research field known as image data classification. To build a corresponding AI model, a “deep learning” algorithm is trained using images from a database as large as possible which have already been assigned to a damage class. The SM&RT database was used which currently contains 1.8 million image files labelled with the CEDEX damage codes. The aim is to enable the algorithm to recognise complex patterns in the existing images and assign them to particular damage classes.

With the right programming and after “learning” successfully, the model can not only distinguish between damaged / undamaged in the second stage, but also automatically identify damage in previously unknown images and assign them to the correct damage class. The final stage, and long-term aim, is to link the data with the necessary repair work, as well as the resources required from the depot and the estimated repair time, by means of a corresponding classification.

The aim of the COOKIE project is to integrate AI-based damage identification into a demonstration application and to test it under operating conditions. In the first stage, we are working to train the AI to

distinguish damaged containers from undamaged ones. Such automated decision-making would already save time in the handling of empty containers, because undamaged containers could then be made available again immediately, without having to go through a long manual inspection process.

To train the AI model, the Cookie project will use both existing CEDEX-coded images in the SM&RT database, including codes for components, damage and repairs, and additional images recorded in a learning phase by HCCR in the course of the project. This entails an HCCR employee (inspector) taking a photo with the Survey Compass Check App, which is ideally supplemented and assisted by a vector in the camera app to ensure that the perspective used is always as similar as possible.

In the second stage, the AI model should suggest a CEDEX combination for the photo that is then processed, e.g. in a 3-stage system:

1) Suggested CEDEX combination correct
2) Suggested CEDEX combination false
3) Manual entry of an alternative CEDEX combination

In addition, the aim in the learning phase is to confront the AI with particularly complex or difficult situations for image recognition (e.g. lighting, background, perspective) and so to determine systematically the limits of its reliable functionality.

In the final stage (the above mentioned long-term aim) the plan for damaged containers is to link the CEDEX code determined using the AI model with container data (storage space, type, container type, year built, customer relevance, demand, availability of spare parts, weather data, ship arrivals, strikes, etc.) and with the availability of staff and equipment. This will create a basis for forecasting the time needed for repairs and the date on which the repaired container is expected to be ready for re-use.

The aim is also to investigate whether and, if so, how the optimal sequence and combination of containers for repair can be determined considering the booking situation of different container types at the depot at a time, in order to achieve the best possible output/availability with the available resources (labour, stackers, etc.). At the same time, this would make it possible to provide customers with information about which containers cannot be repaired in the expected timeframe. Ultimately, the aim is to provide a global overview of M&R capacity and demand while optimising the use of M&R resources.

Note on project status

Work on the project only began in 2020, so no final results can be published yet (Jul. 2021). Reliable results will nevertheless be available by Oct. 2021. The paper can be expanded and updated for the ITS.