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THE E-JOURNAL OF PORTS AND TERMINALS

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FROM THE EDITOR

Margherita Bruno,
Editor

Welcome to this special edition of PTI's journal dedicated to automation! We are delighted to publish this issue in celebration of the eighth Container Terminal Automation Conference (CTAC), set in the beautiful and sunny Valencia.

The maritime industry is currently abuzz with discussions about automation and its future in ports. With the ongoing expansion of global trade, ports and terminals encounter increasing demands to boost efficiency, mitigate environmental impact and bolster competitiveness. In this rapidly changing environment, Artificial Intelligence (AI) emerges as a pivotal catalyst for transformation and a common thread in our journal, offering unparalleled opportunities for innovation and growth.

Kicking off our journal, INFORM takes us back to CTAC North America 2023 in Virginia, emphasizing the importance of software-based optimisation in container terminal operations. Through the utilisation of algorithms and AI, INFORM's flexible approach aims to automate routine decisions, thus freeing up human operators for more complex challenges.

Next, Westwell takes us on a journey through advancements in robotics and AI, particularly focusing on autonomous driving technology within container terminals. Leveraging extensive experience in autonomous fleet operation, Westwell's fleet management system optimises global route planning and traffic coordination, utilising V2X technology for enhanced performance and efficiency.

RBS further underscores the benefits of digital twins and super intelligent engines in optimising terminal operations. By utilising AI-driven problem prediction and optimal resource allocation, RBS' technologies promise substantial advantages, including cost savings, improved decision making and enhanced team collaboration.

Moving forward, Avlino emphasizes the role of AI-powered strategies in revolutionising yard operations, showcasing significant productivity improvements achievable through intelligent container management.

AllRead leads the charge with its Agile Recognition Software (ARS), demonstrating how AI streamlines cargo handling, reduces delays and minimises errors, thereby optimising operations and cutting CO2 emissions.

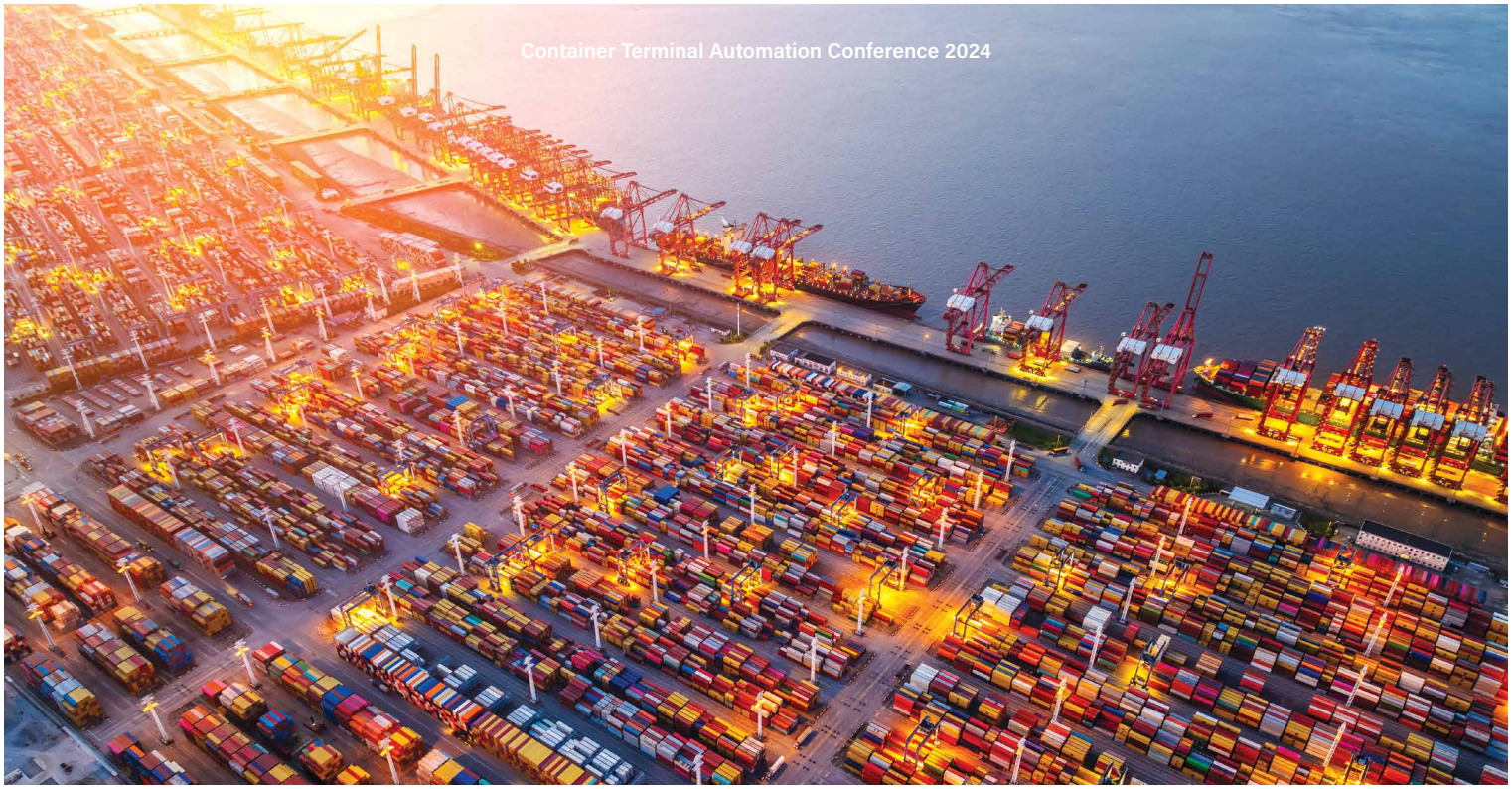
Finally, DSP provides insights into its solution, GEMINI, a digital twin platform that leverages AI to simulate and optimise terminal operations. This solution is essential for modern terminals striving to attain competitiveness and operational excellence amid increasing speed and volume demands.

As decarbonisation must go hand in hand with automation efforts, industry frontrunners such as Rocsys and Kalmar emphasize the necessity of customised solutions for electric vehicles in ports. They also stress the pivotal role of hybrid straddle carriers in reducing carbon emissions and promoting sustainability across port and terminal operations.

Lastly, as automation progresses, safeguarding workers' rights and human value in ports and terminals is paramount. With this principle in mind, FERNRIDE advocates for human-assisted autonomy in logistics, ensuring safety and efficiency while addressing challenges such as labour shortages.

DP World wraps up our journal by exploring the challenges of balancing automation with human involvement, emphasizing the importance of upskilling programmes and collaboration between academia and industry to facilitate a smooth transition.

We hope you find this edition enlightening and that it sparks fruitful conversations on the future of our industry. Wishing everyone attending CTAC 2024 a successful and productive event!



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RECAPPING CTAC NORTH AMERICA: INSIGHTS FROM INFORM

"INFORM HAS PROVEN REPEATEDLY THAT OPTIMISATION IS THE ROUTE TO ENHANCING CONTAINER THROUGHPUT THROUGH IMPROVED ASSET UTILISATION IN CONTAINER TERMINALS."

Dom Magli, Staff Reporter, Port Technology International, interviewing **Matthew Wittemeier**, Director of Marketing and Sales, INFORM

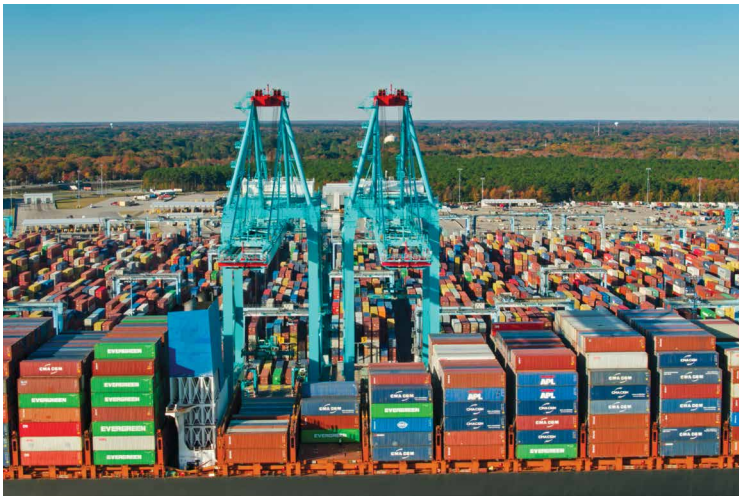
At PTI's Container Terminal Automation Conference (CTAC) North America in November 2023, Matthew Wittemeier, representing INFORM, discussed his perspective on container terminal optimisation. With over 25 years of experience, INFORM emphasizes proven technological solutions tailored to diverse end-user requirements. Their insights shed light on the role of AI and optimisation in shaping the future of automation in port operations.

What technological solution does INFORM believe is best for optimisation?

Matthew Wittemeier: We've been in the business of container terminal optimisation for over 25 years, and we've learned a lot along the way. From our perspective, the best technological solution to achieve "optimisation" is both one that is proven in the real world and one that is flexible to the end-users' precise requirements.

Let's break that down.

There are a lot of startups coming out and saying they can use AI, machine learning, or other techniques to improve container terminal operations. However, we see an equal number of projects fail as these startups lack industry experience, knowledge, or long-term capital to see them succeed in what is a very entrenched industry. Here, proven track records are crucial to success. At INFORM, we've been refining our proven optimisation algorithms for decades across a broad customer base, including some of Europe's largest maritime terminals down to small intermodal facilities in North America and everything in between.



That brings us to the second half of the solution design – a flexible solution. The solution that Container Terminal Burchardkai (CTB) needs in Hamburg, Germany, is widely different compared to what Norfolk Southern's Rossville intermodal terminal needs in Memphis, US. While the core algorithm – say our Yard Optimizer with housekeeping – is the same, how it is configured and implemented varies greatly to ensure each end-user achieves their specific optimisation goals.

We can also look at this question from a technology perspective. There's a saying: "There is more than one way to bake a cake." (Well, that might not be the actual saying, but that is the PG, professional version, at least.) Many technologies like operations research (OR), artificial intelligence (AI), or subsets thereof like machine learning (ML), natural language processing (NLP), generative AI, etc., exist today to apply "smart," algorithmic-based decision making that can be integrated into computer software. Each of these "tools" has a potential series of roles to play.

As an example, ML can be used to analyse past data and derive meaningful insights. At INFORM, we use these insights to enrich the data and data parameters we use in our algorithms. However, ML has its limits. Data insights from 2019 were not indicative of what would happen in 2020 due to the COVID-19 disruptions, and further, data from the Covid era is proving to have limited applications in predicting/informing today's terminal operations. To overcome these effects on the ML tool, one must consider other technologies.

Again, at INFORM, we leverage highly refined and thoroughly

tested OR-based algorithms at the core of many of our optimisation modules. These algorithms leverage currently available data to efficiently model and derive an optimal solution for a particular optimisation challenge in real time. There are no delays to the terminal's operations. OR-based decision making is extremely powerful at optimising the now.

What role does INFORM believe AI will play in the progression of automation?

MW: As an industry, when we think of automation, the first thoughts are typically large, expensive automated hardware like an automated stacking crane (ASC) or automated guided vehicles (AGVs) buzzing around a terminal, moving containers from one place to the next. While these are the highly visible aspects of container terminal automation, these robots rely on equipment control systems (ECS), or software, to drive them. Under the ECS layer exists the terminal operating system (TOS), or central operational data system, where more software collects and disseminates operational messages.

Algorithmic-based AI tools like the add-on optimisation modules INFORM delivers into the market sit firmly within the software environment to improve the efficiency of operations while also improving the utilisation of assets. In a 2 million TEU facility, we would expect to see a 15-35 per cent increase in productivity numbers depending on the assets you're looking to optimise (ASCs, AGVs, etc.). What's more, the efficiency of these algorithms is increasing at rates unmatched on the hardware side.

A typical planning problem INFORM solves today in real-time

"AI AND OPTIMISATION ARE THE TOOLS THAT TERMINAL OPERATORS SHOULD BE LOOKING AT TO IMPROVE HOW THEIR MANUAL, SEMI-AUTOMATED, OR FULLY AUTOMATED TERMINALS PERFORM."

would have taken us 110 years to solve in the early 1990's.

This is because of a 2,000 times increase in physical computing power. This seems impressive until one compares it to the advances in optimisation algorithms over the same period. Linear Programming algorithms, considered the most important class of optimisation techniques by many experts, have improved by a factor of 1.74 million times. In short, over the past 30 years, there has been an 870-times improvement in software's performance compared to hardware's. Significant improvements in automation will undoubtedly come from AI and software as opposed to hardware moving forward.

What effect will automation have on ports and terminals' container throughput?

MW: I think the past 25 years have shown conclusively that automation, on its own, does not significantly improve a terminal's container throughput. It has been argued for the better part of the past decade that with the increase in hardware complexity and quantity of hardware sensors, there have been decreases in equipment productivity. No, overall, automation is not the tool that was promised to dramatically improve terminal efficiency and increase container throughput.

Conversely, INFORM has proven repeatedly that optimisation is the route to enhancing container throughput through improved asset utilisation in container terminals. We started our journey some 28 years ago, about the same time as the first automated terminal in Rotterdam was kicking off. We have shown that algorithmic-based, real-time yard optimisation can dramatically decrease container rehandlers. When paired with our housekeeping (or grooming) algorithm, we can significantly improve the peak period efficiency in terminals. Our crane and vehicle optimisers drive up equipment productivity while also allowing the same quantity of work to be completed with fewer active assets.

This results in driving down OPEX and future CAPEX costs. Our ML module has proven to be extremely capable of improving data accuracy and parameterised data inputs in these decision making processes.

In short, AI and optimisation are the tools that terminal operators should be looking at to improve how their manual, semi-automated, or fully automated terminals perform. They say, "The proof is in the pudding", and our experience and track record prove our point. No other vendor in the industry can match the experience, knowledge, and track record of INFORM in delivering optimisation solutions that work.

What is INFORM's long-term goal for automation?

MW: We firmly believe that software-based decision automation, or "decision making," as we commonly refer to it, should be implemented broadly to free humans from mundane, routine decisions, allowing them to focus

"WE FIRMLY BELIEVE THAT SOFTWARE-BASED DECISION AUTOMATION, OR "DECISION MAKING," AS WE COMMONLY REFER TO IT, SHOULD BE IMPLEMENTED BROADLY TO FREE HUMANS FROM MUNDANE, ROUTINE DECISIONS, ALLOWING THEM TO FOCUS ON MORE COMPLEX, NON-ROUTINE CHALLENGES."

on more complex, non-routine challenges. As already noted here, we can automate 90-98 per cent of daily operational decisions. Think of what your operations team could be doing with their experience and knowledge if they weren't focused on yard planning or work order assignments. The value-added potential is huge!

What are INFORM's plans for 2024?

MW: Without giving too much away, we have quite a few exciting things in the pipeline. Of course, our principal objectives are to deliver solutions to our current customers. With active deployments at PSA, DP World, and Norfolk Southern, to name a few, we have several new customer solutions in the works, and we're looking forward to bringing these solutions live. This comes on the heels of significant upgrades with TraPac and GCT Deltaport in 2023.

Furthermore, and as we have become known for, we've got some interesting developments in the works. We have just kicked off a project with a major American terminal operator to help them better understand how to improve their maritime terminal's yard throughput using our yard optimisation and machine learning modules – something we've been doing with CTB in Hamburg for nearly two decades. We're also working on the challenges that vehicle electrification will bring to terminal operators when deploying at scale, and we've been looking at the continued development of ML applications. We've built an ML algorithm that can accurately predict week-to-week dwell time in North American intermodal facilities. Cool stuff!

ABOUT THE AUTHOR:
Matthew Wittemeier, CPM is Director of Marketing and Sales at INFORM's Terminal & Distribution Center Logistics Division where he also sits on the board tasked with driving the company's customer-facing business strategy. In his time with INFORM, he has become a thought-provoking contributor to many industry publications and conferences. He's co-author of the multi-award-winning 2038: A Smart Port Story – a novella about the future of technology in terminal operations and the social challenges it may bring. In addition, he is a member and judge at The Academy of Interactive and Visual Arts (AIVA), is a Certified Practicing Marketer, and sits on several boards. He holds a Bachelor of Management and Professional Studies.

ABOUT THE COMPANY:
INFORM specialises in AI and optimisation software to improve operational decision making. Based in Aachen, Germany, the company has been in the optimisation business for more than 50 years and serves a wide span of logistics industries including ports, maritime, and intermodal terminals. With a broad range of standalone and add-on software modules, INFORM's unique blend of algorithmic-based software expertise, rich industry experience, and big-world thinking delivers huge value for its customers.

More Info: **https://infrm.co/terminal**

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AUTONOMOUS TRANSPORTATION IN TERMINALS WITH GLOBAL PATH PLANNING AND V2X

Dr. rer. nat. Chao Chen, Head of Research and Innovation Group, Westwell

INTRODUCTION

The latest research progress in robotics and Artificial Intelligence (AI) helps autonomous driving technology become more and more applicable in daily life and industry scenarios. The robotaxi and the autonomous trucking systems are built mainly based on vehicle on-board sensors and computing units. As the operation domain on public roads involves large-scale scenarios regarding locations and objects, an intelligent vehicle must be able to make its decision with its own perception and localisation inputs. Although many V2V and V2I solutions are employed to help deal with complicated situations, the system coverage is limited. The management system of a fleet of robotaxi or autonomous trucks is usually rather a platform managing ride-sharing or logistic orders than a system coordinating the traffic flow, because the majority of road occupants are still manually driven vehicles.

On the other hand, if an autonomous vehicle is working in a closed environment, for example container terminals or logistic hubs, the operation domain is well-defined and bounded in the region. Without a doubt, the problem complexity is reduced by orders of magnitude, especially the corner cases. In addition, a centralised traffic management system can greatly improve the productivity of the autonomous fleet by optimising the routes to reduce travel time or waiting time. The reasonable size of operation space enables full coverage of smart infrastructures to boost the perception range of a single vehicle. The information gathered either by smart vehicles or roadside units can be uploaded and help the central system to make global decisions.

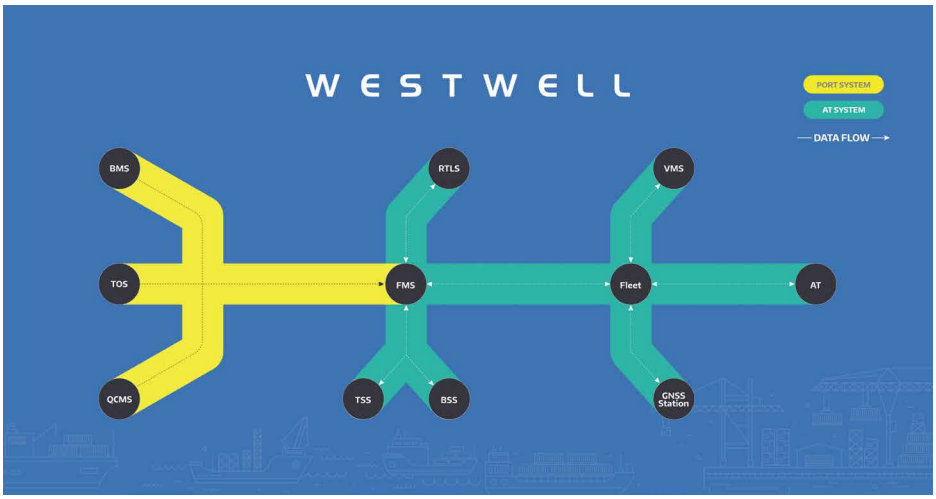
During the years of pioneering autonomous fleet operation in several container terminals, Westwell gained a significant amount of experience in managing and optimising operations. The team has developed a fleet management system that addresses global route planning and coordinates the traffic with V2X data. The following sections will make a brief introduction to the fleet path planning approach and the V2X applications with remote vehicle localisation solutions.

FLEET PATH PLANNING

Evolutions of Fleet Path Planning

A fleet management system (FMS) in container terminals started with the deployment of automated guided vehicles (AGV). At that time, the AGV operated in areas isolated from manual trucks, FMS had complete knowledge and control

“DURING THE YEARS OF PIONEERING AUTONOMOUS FLEET OPERATION IN SEVERAL CONTAINER TERMINALS, WESTWELL GAINED A SIGNIFICANT AMOUNT OF EXPERIENCE IN MANAGING AND OPTIMISING OPERATIONS.”



"THE LATEST DEVELOPMENT OF THE PATH PLANNING STRATEGY IS TO COMBINE THE GLOBAL PATH PLANNING IN FMS AND THE LOCAL PATH PLANNING FROM AT."

of the traffic on the field. Routes and paths could be designed and optimised offline. The fleet could operate as a machine with well-synchronised clocks. Only limited exception handling was required. In this system, a single AGV only needs to have basic collision avoidance functionality. Its major task is to follow the exact trajectory commanded by the FMS. An AGV doesn't need to negotiate with the traffic, as the FMS already sorts out all the sequences and resolves all the conflicts.

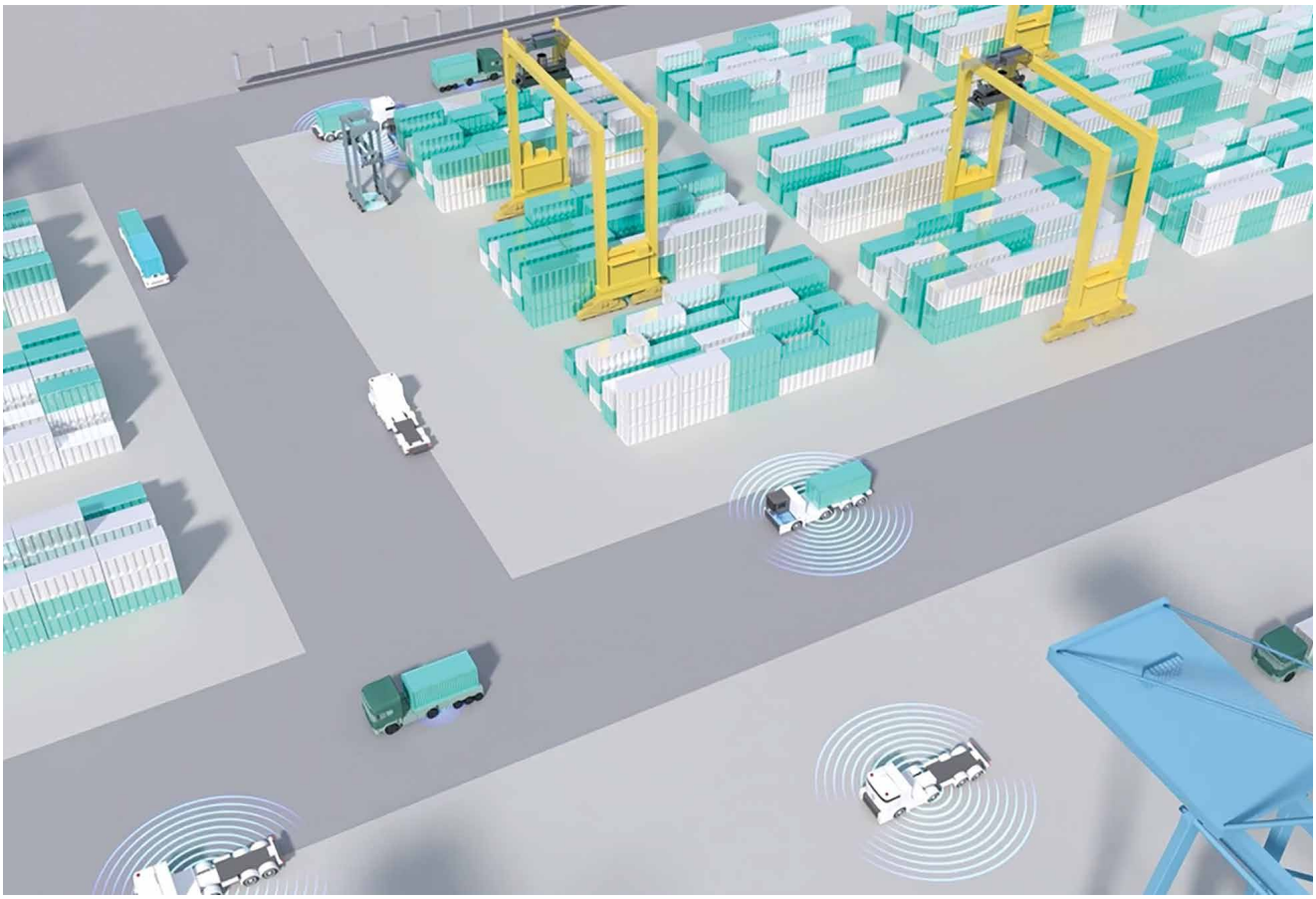
The situation becomes more challenging with mixed traffic scenarios, as an autonomous truck (AT) operates together with manual trucks without time or space separation. The most straightforward solution is to let the AT determine its route and path, and FMS only provides the destination and some middle waypoints. This approach is the same as the robotaxi on public roads, which is easy to scale and supports many ATs. However, since an AT only has a limited range of sensing, it can only come up with local optimal decisions. The situation becomes even more tricky in conflicts, for example, uncontrolled intersections or merges. Rules need to be carefully designed to avoid deadlock of multiple ATs. To solve complicated deadlocks and optimise the traffic flow, FMS started to act as a coordinator in many cases.

Thus, Westwell's global path planning is born again, but quite different from the initial one. The latest development of the path planning strategy is to combine the global path planning in FMS and the local path planning from AT. FMS can optimise the traffic flow from the global perspective, while AT has the flexibility to manoeuvre in its close environment.

Cooperation between Global and Local Path Planning

The figure above illustrates an example of Westwell's system blocks in the container terminal. The yellow parts are the existing port systems and the green ones are the AT systems. According to this architecture, FMS is the centre node communicating with the terminal operation system (TOS), block management system (BMS), quay crane management system (QCMS) and the AT fleet. Besides its basic functionalities for task management, exception handling and workflow management, it also plans and manages AT paths on the global level for the following purposes:

1. Multi-vehicle spatiotemporal coordination, which continuously observes and grants AT access to a certain road or lane segment. The global path is defined as a sequence of paths or lane segments. An AT receives an operation task with a global path, but it can only traverse the lane segment which is granted by FMS. This method gives FMS higher priority to control the usage of certain space and time.
2. Combination of global path and local path, which gives an AT flexibility of local decisions. Even though the global path is controlled by FMS, an AT can request additional space to travel. For example, if the current lane is blocked by a vehicle waiting for service, AT can initiate an overtake with a local path changing to the bypass lane. If FMS checks the condition is satisfied, it grants the access to bypass lane for overtaking and updates the global path accordingly.
3. Traffic flow and intersection management, which balances the utilisation of road resources. The fleet provides information about the traffic situation. In this case, FMS can optimise the global path selection to avoid congested lanes and intersections. Decisions can also be made with the crane, especially in the yard.
4. Deadlock resolution and collision avoidance, which guarantees deadlock-free and safe operation of the fleet. After accepting the operation task and global path from FMS, an



AT reports its state and local path in a constant frequency. FMS continuously checks the paths with conflict or deadlock. By setting the speed or reserving the lane segment, FMS can resolve any deadlock in advance and reduce any potential risks.

Westwell's global path planning depends on the precise knowledge of the entire traffic situation. FMS has access to the autonomous fleet state and crane status by design. However, if the manual traffic data is missing, it can only get the big picture with a significant size of autonomous fleet. In this case, the V2X infrastructure is developed to fill the gap.

PATH PLANNING WITH V2X

Vehicle Localisation with Connected Device and Surveillance System

To gain a full vision of all the traffic in the terminal, there are several ways to detect and track non-autonomous vehicles. The most direct method is to install a connected device with global localisation in a vehicle. It is applicable for all terminal-owned vehicles with a certain amount of cost. But it is almost impossible to equip every external vehicle. With the help of AI technology, detecting and tracking a vehicle with a camera image becomes state-of-the-art technology. As many terminals have high surveillance camera coverage, the CCTV video image can be used to detect and track vehicles and pedestrians. Following this idea, a terminal surveillance system (TSS) called WellSecurity is developed to detect and map objects to terminal road networks. It can then identify rule violations and hazardous situations.

As illustrated in the system block diagram, TSS is connected to FMS. It sends the real-time vehicle and pedestrian location to FMS. Combining all the information, Westwell's FMS can build a birds-eye view of the terminal with all the moving objects for global planning.

V2X Application Scenarios

One good use case is at the intersection entering a block. Since an AT has a limited sensing

“WESTWELL'S FMS CAN BUILD A BIRDS-EYE VIEW OF THE TERMINAL WITH ALL THE MOVING OBJECTS FOR GLOBAL PLANNING.”

range or may be blocked by other obstacles, it is not always aware of the situation at the first several bays of the block. In case of a manual vehicle stopping at the first bay, AT may end up queuing behind and blocking the intersection. With V2X detecting the obstacle in advance, AT can choose the bypass lane or wait outside the intersection.

Another effective scenario is helping AT to navigate through congested traffic under quay cranes. It is common that due to the busy loading or discharging operation, multiple lanes under quay cranes are blocked. Rather than waiting in line, FMS can let an AT change lanes and move to an unoccupied crane or cut-out to use a free lane to bypass any vehicle that is waiting for service.

The V2X can provide information beyond the sensing range of an AT. Therefore, a Westwell's AT becomes smarter than an experienced human driver.

CHALLENGES AND OUTLOOK

After implementing and deploying the FMS and TSS with global path planning and V2X functionalities, we see a significant boost in fleet performance even in complicated mixed traffic operations. There are still several challenges and room for improvement in this system. Firstly, the handshake between global and local path planning requires reliable and low-latency network communication. Second, the flexibility of the AT local planning asks FMS to process the change requests in time and deal with swarming intelligence problems. Rather than commanding the ATs one by one, it is desired to help them to cooperate. With the V2X information about manual vehicles, AT can learn from experienced human drivers to handle difficult situations. The ultimate goal is to achieve close or beyond human fleet performance with less infrastructure burden and excellent scalability.

ABOUT THE AUTHOR:
Dr. rer. nat. Chao Chen is the Head of Westwell's Research and Innovation Group. He received his PhD degree in robotics and embedded systems from the Technical University of Munich and has more than 15 years of industrial experience in autonomous driving and intelligent vehicles.

ABOUT THE COMPANY:
Westwell is a global provider of autonomous driving solutions. The company unlocks potential through AI and new energy, striving to pioneer intelligent services globally. To date, they have deployed hundreds of commercial autonomous vehicles and systems worldwide. Westwell's products/services serve freight logistics scenarios like seaports, dry ports and plants. The company serves more than 200 clients in 18 countries.

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