Emulation for terminal operating systems

The following article is based on a White Paper, produced by Yvo Saanen, a partner in TBA Nederland

Container terminals are facing ever-growing volumes and are searching for solutions to increase throughput capacity without expanding their physical footprint, and at the same time service larger ships within the same time window. A good terminal operating system (TOS) is playing an increasingly important role in today's terminal operations supporting terminal planning, scheduling, equipment control and stow planning. TBA Nederland has developed a tool to test and tweak a TOS and to train operators prior to implementation and during daily operations.

This "virtual terminal" solution ensures that any modifications to the software or changes to the operation can be implemented without risk. It has been successfully applied at the software replacement project at ECT Rotterdam and is running in pilot form at the APM Terminal (APMT) in Aarhus. On its way is the support of the development of the TOS for APMT's new high density terminal in Portsmouth, Virginia.

The emulation tool is called Controls, and it allows for insight to be created and parameters fine-tuned during software development, commissioning, and during training and operations. The tool itself, together with the user of the tool, forms the success factors for the application.

To support the terminal in the use of the emulation tool, a regular on-site "fitness check" is carried out by TBA, during which terminal performance under the revised circumstances is reviewed and the parameters of the TOS are optimised to the changing conditions.

An additional module called Scenema (scenario manager) is also available, which can create all kinds of realistic operational scenarios. Scenema can be used to create scenarios for future situations or change container flow parameters, for example, more rail moves, more transshipment and so on. It allows the terminal to look into the future to see whether the terminal can cope with increased density and operations. In a greenfield situation, it allows for creating a consistent information flow to feed the TOS within formats (eg, Baplie) the TOS understands.

Controls sits alongside the terminal TOS and feeds assumed information into it, so that a myriad of "what if" scenarios can be tested without taking the plunge into the unknown and risking a major change without fully understanding the consequences. In more depth, it may answer questions regarding the setting of parameters that typically appear in modules such as Expert Decking or PrimeRoute from Navis.
The major objectives of Controls are: lreduction of the risk of complex software development, by providing an early test environment that represents the terminal in an as realistic as possible manner
lassurance of terminal performance, expressed in various performance indicators, such as QC productivity, equipment utilisation and productivity, and truck turn-around time
limprovement of the insight into the TOS by observing short- and long-term effects of certain configurations of the TOS parameters.

Training of TOS users in a virtual environment

Iwithout the risk of productivity loss, the emulation tool can be used to perform realistic training for operators

IVisualisation of operations to increase the understanding of the operation.

The essence of the emulation is to provide a tool that acts as a very realistic virtual terminal. A tool that provides a valid representation of the physical processes at a terminal (equipment behaviour, driver behaviour, operational scenarios – gate arrivals, train arrivals, vessel arrivals), which can be linked to the TOS in such a way that the TOS treats the tool as the “real world” (this means via the already present interface between TOS and equipment), and which can be used to run operational scenarios, either as occurred in the past, or as configured by the user. The emulation model includes a representation of all relevant processes at the terminal – ie, the lay out (for example, yard, rail terminal and quay cranes), a model of the equipment (kinematics, driver behavior, routing, disturbances, and availability), and performance measurement functionalities. The TOS communicates with the emulation as if it were communicating to the machine’s radio data terminal. The emulation interprets the incoming information, executes the tasks and reports back whenever required. The interface is identical to that used in the real operation, so that the TOS does not need to be adjusted. This is a core requirement of the emulation approach, because changes may cause deviations from what would happen in a real operation.

All possible interactions between the TOS and the controlled equipment are represented as far as they affect performance. These interactions basically follow a pattern of an order going from the TOS to the equipment and notification of equipment availability or position updates sent back to the TOS.

The emulation also creates external arrivals, from gate, train or ship, that have to be fed into the TOS. The messages for these processes have to be defined – typically this is a host system functionality – and are additional to the operational messages, since in reality these events just happen and are registered by humans. The same is true for the time management, as the emulation model and the TOS can, and preferably will, run faster than real time. However, in that case both programs have to be synchronised on a continuous basis. Without time synchronisation, the emulation tool can run in real-time mode only. This functionality allows faster feedback and fact-finding.
The emulation tool comprises all relevant components at the terminal, such as quay cranes, RTGs/RMGs, reachstackers, straddle (shuttle) carriers, terminal trucks. Also, all relevant locations in the terminals are defined, such as container stacks, the gate and the truck transfer zones, the MT stack, reefer plugs, and a place for OOG containers. The dynamic movements of equipment are based on equipment kinematics and on the possible interaction between equipment at the terminal (for instance, two straddle carriers that want to access the same row in the stack, will lead to one straddle carrier waiting). Each terminal component is modelled in such that all specified scenarios can be tested in an accurate way.

Typical features present in the emulation tool:

Validation mode – in this mode the vessel, yard, and/or gate planner validates whether the plan for upcoming operations are well-defined, in the sense of resource allocation, yard organisation and equipment deployment.

Fine-tuning mode – the production run (say, one day of operation) can be started over and over with the same or different parameter settings (configured in the TOS). The TOS may support this by capture and replay functionality. After a run, the output is available in the emulation tool as well as an advanced data analysis tool, delivered as part of the tool. Results from multiple production runs are uniquely recognisable afterwards, and stored in a database (also part of the package).

The layout (roads, stacks, apron, gate and so on) can be specified in the emulation tool. If something changes, the user can change it in the tool accordingly. Preferably, the input for these configuration parameters is used from the TOS. When the configuration files (.ini) used by the TOS are disclosed, Controls will use these so that updates in the TOS are automatically reflected in the emulation tool.

The specification of the control parameters – specifying the yard operating strategy (allocation ranges, decking rules) – and equipment control settings (work pools, way of assigning, for instance, remarshalling moves) are specified in the TOS identical to a normal operation. The speed of the tool depends on the length of the run. The emulation is capable of running five to 30 times faster than real-time (of course, this requires the TOS to be able to run faster than real-time as well; it also requires time-synchronisation between TOS and emulation tool in some TOS systems).

During the run, and at the end of the run, the user can create some visual representations of the yard (views). For instance, visualisation of the locations of containers with a specific property (voyage number, size, weight class, IMO class, type). In replay mode, all movements as well as order status can be reviewed at any given point in time.

The emulation tool can run in "animation" mode. Then the user can follow the execution of specific moves (in a true-to-scale 2D animation), and tune the parameters online. All equipment will be "clickable" and represent its main properties at that point in time. The position of the equipment will be updated at least every five seconds (real-time).
Typically, a TOS does not generate detailed statistics with regard to the equipment. However, the emulation tool will generate detailed statistics that go beyond QC productivity and truck turnaround time. These statistics will enable much more detailed analysis of the reasons for a productivity changes, for example, longer travel distances.

Controls generates output of a single experiment – an experiment is a combination of the setting of the control parameters, the message log of a certain period, and the setting of the equipment – in the form of text files that can be loaded to MS Access /MS Excel, so that the data can be easily analysed. The following commonly used data are registered, but other measurements are also possible:

registered quay crane moves per hour
quay crane idle time
service time of road trucks
productivity of straddle carriers/terminal trucks (productive and non-productive moves)
status of stacking equipment (idle, working, waiting for other equipment)
detailed equipment behaviour (average distance per move, average speed, status, etc)
average filling rate of the yard
average filling rate of ground slots.

Furthermore, the actual state of the yard is available as a table and by means of visual representations (so called yard views) that show:

stacking height of each pile
location of containers that have a certain property (voyage number, POD, weight class etc). The availability of this information depends on data being supplied by TOS but if input via scenario manager will be available. In order to evaluate the parameter settings (for example, allocation ranges), algorithms, and allocation of resources to points of work (vessel, rail, gate, yard), operational scenarios have to be defined. These are either real scenarios, meaning a replay of a past existing operation, or are representative created scenarios, for instance for peak circumstances (full yard, 20% volume growth, or a full berth after a storm) or breakdown situations.

Each scenario execution will consist of an initialisation step during which the user (or the scenario manager) configures the initial yard (in principle, loaded from the TOS), and plans the operation. These settings can then be stored, so that this experiment can be repeated without initialising again. After the initial yard is loaded, the experiment run will be executed. The experiment run will cover for instance eight or 24 hours of operation – the ability to run longer
experiments depends on the TOS. The emulation tool is capable of running as long as the TOS controls the operation. Attended runs (meaning an operator interacts with the TOS as in a regular operation) may last as long as the user wants, as the emulation behaves as the real world would behave. Unattended runs, however, depend on the capability of the TOS to run without an operator controlling it.

The experiment runs may be started over and over for various scenarios. The output of the experiment runs will be available in the simulation environment as well as in a standard Microsoft database (MS Access) format. Results from multiple experiment runs will be uniquely recognisable afterwards.

TOS performance can be assessed by comparing the performance of various simulated operations (for example, QC productivity, truck and rail service times, number of shuffle moves and so on).

The emulation software developed by TBA has to date been used on several projects, some in the container terminal industry, and others outside – including an automated baggage handling system, and a large concrete factory, both 24/7 operations where the reliance on operational software is also very high, as are the costs of stoppage.

In four of these projects, the emulation was used to support the introduction of new software and it proved to be a very valuable tool, enabling the development team to dissolve about 95% of the errors that typically are found after going live.

Furthermore, the visualisation accompanying the emulation provided useful insight during the process for general management as well as for software experts. Where usually the customers of a new system have to wait until the system goes live to be sure that it would do what they wanted and expected, they were now able to operate a virtual operation way before the system goes into the real operation. In addition to systems verification this gives the possibility to train future operators, and also allows for early feedback from the future users.

It also enables the team to stay focused on performance of the terminal. Typically when a new system is being introduced, the focus shifts from performance to "getting the thing to work". By using the emulation tool a continued focus could be kept on actual operating performance, quay crane productivity, equipment utilisation, stacking efficiency, truck service and so on.

In another case, the emulation was applied to assess the quality of the dispatching of straddle carriers for handling gate traffic. It appeared from the experiments that the truck turnaround could be reduced by more than 30% on average, and the peaks by 50%, by just changing the dispatching algorithm and parameters. For a minimal investment – it implied some changes to the TOS – the service-to-trucks could be improved drastically, or in other words, the number of straddle carriers required to handle a certain truck peak could be reduced, saving labour and equipment costs.

The basis of the emulation tool has been developed over the past seven years. TBA's team, in cooperation with terminal operators, has carried out a number of projects. During these, the need
for simulation became apparent and therefore the development of a very detailed simulation model was started. The design philosophy of the simulation is based on two pillars: reusability of components and close relation to structures in reality for both software and hardware.

Because of our background as system engineers, the preciseness of modelling has been a major issue and has led to a high level of detail. For instance, all models are based on a co-ordinate system, which enables us to animate true-to-scale. Besides the verification and validation of the equipment, much attention has been paid to depict the control rules – for example, berth assignment, crane assignment, TT assignment and realistic yard planning. Container terminal-specific issues like container sequence, weight dependence and last minute changes are taken into account. All models have been validated in close co-operation with operational experts from various companies. The team that has developed the simulation models consists of simulation experts, operational experts and equipment experts. The expertise with emulation builds upon several projects across industry. One project of particular interest is the development of emulation tools for Navis and Gottwald for the software replacement project at ECT. Here, extensive experience has been gained with the connection to both Sparcs and software controlling automated equipment. More recently, TBA Nederland and Navis have entered into a partnership to offer Controls to Navis customers, although as mentioned earlier Controls can work with any commercially available terminal software.

Controls has been used by DPI Terminals in the development of its new terminal in Pusan, Korea. Robert de Belder, manager terminal systems, says: "Stress testing with Controls was part of the evaluation of our new terminal operating system. Thanks to the stress testing, we were able to debug our TOS and evaluate the response times of our application. We expect to use Controls in future to evaluate the logistic performance of our TOS."

As TOS become mission critical in terminal operations, it is crucial that any new systems or modifications are not implemented without full assurance that what is supposed to happen will happen, and what the system is supposed to do, it will do. If the terminal operator wants to make changes to his operation he needs to do so in full knowledge of all the ramifications. Being able to emulate the real world without the risk of major failure gives a level of comfort that has not been previously available. Furthermore, the ability to tune off-line – not affecting the real operation – and to train control room operators in a playing environment rather than the real thing, will give the opportunity to improve productivity, and therefore the profitability, of a terminal.

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IN DEVELOPMENT

The importance of IT in achieving high levels of productivity in terminal operations is now widely recognised. Stories abound of terminals increasing throughput or reducing equipment use
or generally running a smoother more profitable operation very quickly after the installation of a 
new software system. Selling a product that is less tangible and visible than a crane or a lift truck 
is something of a problem for software suppliers when competing for investment money from 
terminal operators but the vendors are working hard to improve their offering and to give 
terminal operators the benefits of new software technology that is becoming available.

APL Kaohsiung has used Kaohsiung Container Terminal number 3 as its major Taiwan base for 
import, export and transhipment for 25 years. Some three years ago, the terminal implemented a 
new Navis terminal operating system (TOS) comprising Sparcs and Express and over the 
subsequent years has seen some dramatic throughput and productivity benefits: increased total 
average moves per hour from 28.55 to 35.15; decreased re-handles by 22%; and reduced staff 
costs by 15% – and all this achieved when using only six of seven cranes.

Tideworks Technology has its Mainsail terminal management system installed at more than 50 
terminals and has recently announced the integration into Mainsail of a product supplied by 
Vantage OPS of Austin, Texas, designed to help terminal operators better manage their business. 
Vantage provides Mainsail users with what Tideworks describes as "out-of-the-box operations 
dashboards and key performance indicators to improve decision-making and communication, 
optimise execution of operations, increase profitability and financial predictability and exceed 
customer and regulatory requirements".

Total Soft Bank (TSB) of Korea is a major supplier of terminal operating and planning systems 
with its Catos operating system installed in more than 70 terminal worldwide, including 15 in 
Japan. TSB also has a major venture under way to penetrate the China market.

TSB is working with Modern Terminals, Hong Kong's longest established terminal operator, to 
develop and implement the "next generation" of terminal operating system called Motos 
(Modern Terminals Operating System). When complete, TSB and MTS will work together to 
market the new product in China. Based on J2EE (Java 2 platform, Enterprise edition) the system 
re-write will change the whole architecture of Catos and provide a more flexible and more 
productive system that will be particularly appealing to smaller and mid-size terminals. TSB says 
the new application will be ready in early 2006.

Navis also has a major rework of its popular Sparcs terminal management system under way and 
an official launch is planned for NavisWorld 2006, in April in San Francisco.

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