

The Virtual Terminal: Visualizing Automated Container Terminals

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Automation in maritime container terminals is gaining momentum as the advantages in terms of total life cycle costs have become apparent in western countries. However, expertise and experience in the design, development and operation of automated terminals is still limited. Many stakeholders or actors are involved in the design process and the entire process is supported by a substantial amount of documents created by different actors. These actors cover a wide range of perspectives, use specific information carriers and terminology, and have their own interests while having sometimes little understanding of the interests of others. A common framework of understanding is lacking which makes the communication within the design process problematic, and could result in suboptimal designs. Currently tools like simulation and animation are used to support communication in the design process. These tools are costly to use, have long throughput times to develop and often do not have an accurate realistic representation of the design. We propose to use a 3D visualization environment to present the design of automated terminals. This virtual environment, called the Virtual Terminal, can be used as a common framework for understanding and as a communication medium. The Virtual Terminal should overcome the disadvantages of the tools that are currently used. By automating the generation of 3D environments of container terminals based on CAD drawings and by using this virtual environment as a framework to structure existing knowledge, the Virtual Terminal can support decision makers throughout the decision making process. To evaluate the Virtual Terminal a case study is presented on the design process of a state-of-the-art automated container terminal.

Keywords: visualization, 3D virtual environments, automated container terminals

1. Introduction

In this introduction, we will begin by discussing the challenges faced in the design of automated container terminals. We will see how different actors are involved in the design process and which additional difficulties arise when terminals need to be automated.

1.1 Automated container terminals

Automation is gaining momentum within the maritime container terminal industry. Automation in container terminals replaces manual labour by computer controlled equipment to handle containers. A number of container terminals has been automated in the recent past, see Table 1. Furthermore, more container terminals will be automated in the near future.

Table 1. Examples of automated container terminals

Terminal	Year	Automated Technology
ECT (Rotterdam, The Netherlands)	1989-1993	RMG* and AGV†
HHLA-CTA (Hamburg, Germany)	2003	RMG and AGV
APM Terminals (Virginia, USA)	2007	RMG
Euromax (Rotterdam, The Netherlands)	2007	RMG and AGV
Hanjin (Algeciras, Spain)	2010	RMG

Traditionally, the handling of containers has been a labor intensive industry. The advantages of automation of container terminals compared to manual operated terminals are numerous (Rijssenbrij 2000; Saanen 2004; Versteegt 2004; Pielage 2005):

- *Automation leads to lower life cycle costs.* The higher initial investments are compensated by lower operational costs. Automated terminals are less sensitive to shortages in labour and increasing labour costs.
- *Automation improves safety and labour circumstances.* Less people are required to physically handle containers, which leads to a reduction of repetitive and dangerous work.
- *Automation can significantly reduce the level of damage* to containers, cargo and container handling equipment. Automated equipment operates more precise than human operators.
- *Automated equipment can easily be electrically driven.* This results in less local sound and local air pollution.
- *Automated systems can increase the level of service* delivered to the customers. Automated terminals can operate on a continuous 24/7 basis and with a consistent level of performance. This increases the service levels that can be offered to the customers.

The design of automated container terminals is not a trivial task (Saanen 2004; Pielage 2005). Firstly, there is little experience in designing automated terminals. A limited number of automated terminals have been designed and built until now, see Table 1. There is little experience with such design processes. Secondly, automated container handling equipment is more complicated technology compared to traditional human operated technology. The

* Rail Mounted Gantry Crane

† Automated Guided Vehicle

systems integration of the automated components is a challenging task. Thirdly, the design process has a long time span compared to human operated terminals. Frequent changes are made throughout the entire design cycle. It is difficult to keep track of these changes. Fourthly, many actors are involved in the design process. Each actor has its own goals, specific information needs and objectives. The actors also have different disciplines. The goals and objectives are often unclear and/or conflicting. The information needs differ for each actor. This results in a situation in which there is no common framework for shared understanding. This makes the communication between the actors cumbersome and increases the chances that actors will only focus on their own goals and objectives. This can lead to suboptimal designs of automated container terminals.

All in all the design space for designing automated logistic systems is large, as shown in Figure 1. Many choices and decisions have to be made and many actors are involved in the design process. Decisions made for one part of the terminal directly and indirectly influence other choices that need to be made. Some of the most important choices and decisions are:

- The layout will be used for the terminal (perpendicular or parallel orientation).
- Number of quay cranes or ship-to-shore cranes that will be used.
- The type of equipment that will be used for stacking, including the dimensions and number of stack equipment.
- The type and number of horizontal transport equipment that will be used.
- The interfaces between waterside operations stack operations and rail/road operations.

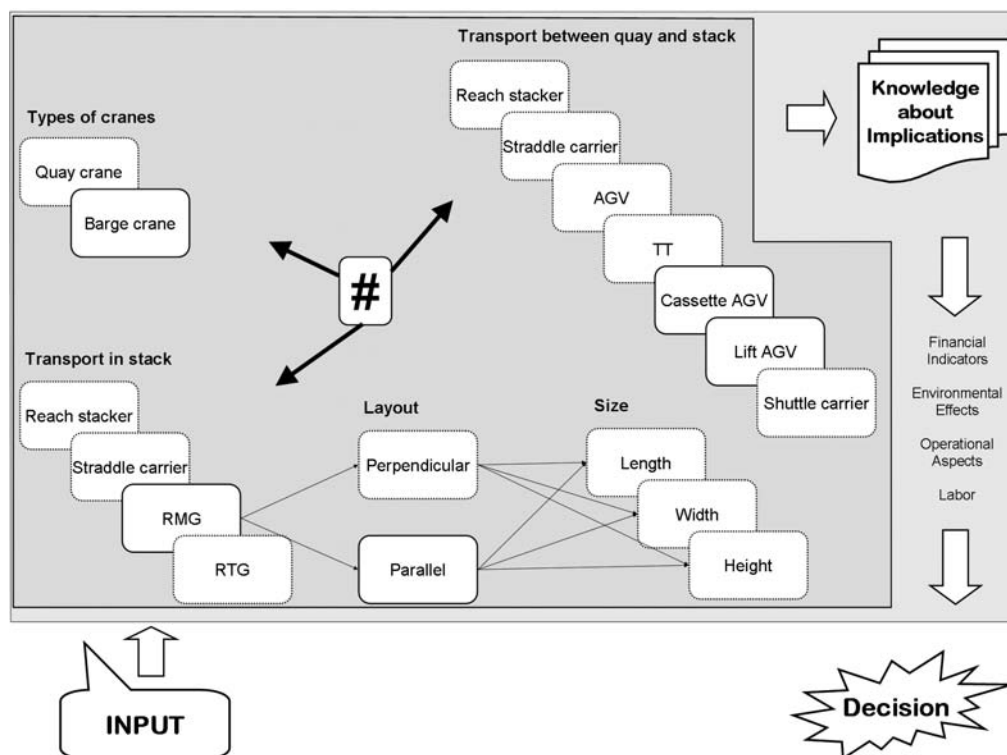


Figure 1 Design space (based on Holsapple (2008))

The design of automated container terminals is a complex process because of the issues mentioned above. Communication within the design process is cumbersome and challenging. Traditionally, simulation models and visualization tools have been used, among other, to support the communication. However, both tools have a number of disadvantages

- Constructing simulation models and 3D visualizations is a costly exercise.
- Constructing simulation and visualizations requires long throughput times while the design changes many times. These changes occur so often that it is difficult for the modellers to ‘keep up’.
- Creating simulation and visualizations requires a high level of expertise that is often not available within a container terminal operating company. Externals have to be hired to execute the visualization.
- The simulation and visualizations mainly cover the perspective of one actor and focus on his goals and objectives. They are not well used for a multi-actor and multidisciplinary environment.
- They are often pre-recorded visualizations or animations with no or little user interaction.

These disadvantages result in a limited use of simulation and visualizations in container terminal design projects. We want to support the designer of automated containers by improving the communication within the design process by providing a common frame of reference. We aim at providing a common frame of reference by using a software based visualization tool that we developed, called the Virtual Terminal (VT). The Virtual Terminal is based on recent research and developments in area of visualization environments and simulation.

We identified a set of requirements for the Virtual Terminal. The Virtual Terminal has to overcome the disadvantages of simulation and visualization mentioned before. The requirements are:

- Easy and quick construction of presentation material.
- Present realistic and compelling 3D imagery of an automated container terminal.
- Contain the vast amount of information gathered from different sources.
- Serve as a communication medium between actors.
- Provide the context and an overview of the knowledge present in the container terminal.
- Provide interaction with the actors involved.
- Contain sufficient details for decision making.

These requirements were identified by interviewing members of design teams of both human operated and automated terminals.

2. The Virtual Terminal

The Virtual Terminal is a 3D visualization software tool for automated container terminals. The tool is intended as support during the design of automated container terminals. Four important aspects characterize the VT: the automated extraction of the virtual environment description from design drawings, a realistic 3D visualization of the virtual environment, the possibility to structure information into context and finally the means for communication and presentation.

Creating a virtual environment is a tedious task which usually involves manual labor requiring weeks or months of work. During the design process of a container terminal, this waiting-time would be a huge set-back. Commonly, 3D impressions are made only once. The design process is, however, not yet completely finished. This means that changes in the design have to be incorporated in the 3D impressions. Practice shows that this is not done,

because of the high costs. The Virtual Terminal is linked to AutoCAD. Any changes in the CAD drawings can be automatically incorporated in the Virtual Terminal. Having a mean of translating these drawings to descriptions of virtual environments, can therefore facilitate the task of constructing the virtual environment and significantly shorten the time needed for it.

To achieve this, an AutoCAD plug-in has been developed that translates the design drawings into an XML-file that serves as a description for the virtual environment. The translation is based on an ontology for automated container terminals: this ontology allows a mapping of entities in the 2D design drawing to entities in the virtual environment. This approach on translation can best be described as an extension to the library based approach on data translation from CAD to VR as described by Whyte, Bouchlaghem et al. (2000).

With a valid description of a virtual environment, a realistic 3D presentation is possible. To achieve this, 3D models have been developed based on blueprints and/or CAD drawings of equipment provided by the suppliers of container handling equipment. Furthermore, detailed photographic material was made and collected. The blueprints and photos were joined into high-detailed virtual elements that can be used in the VT.

The ontology, which is used for the mapping from design drawings to virtual environment, also serves as the structure for information which can be put into context. To each entity in the ontology, and therefore in the 3D virtual environment, context specific information can be attached. This information is not limited to any format allowing the use of textual documents, spreadsheets, websites, etc. This freedom is left on purpose as the format in which information is stored for a given project varies widely. Each entity containing information is thereafter marked, which is intended at getting the attention of the users. Besides information, the ontological structure provides an interface for external sources e.g. simulation and real-time data feeds. The VT therefore results in the central point of resources.

2.1 Software architecture

To have a better understanding of the VT, a component diagram is presented in Figure 2: the component diagram allows us to present the high-level, architectural view of the system.

The *World* component is the central point of the system, as such the meeting point of information. Every activity goes through this component as so keep a consistent state of the system. This component feeds the output components: the *3D visualization* and the *2D textual output*. The *3D visualization* is only in charge of visualizing the automated container terminal in a realistic manner, while the *2D output* provides the means to show all other information: textual information, annotations, and documents. The *World* component is initially fed by the *WorldLoader* component which on his hand gets the information from the *Design Drawing Translator* component. These components are thus in charge of translating the design drawings to a format understandable to the VT. The *World* component continues by gathering information from other external resources as for instance a database, a simulation data feed, or other resources found to be essential in the design process. The last component, the *User Input Interface*, is in charge of the interaction with the user: selection of entities, input of information, and navigation.

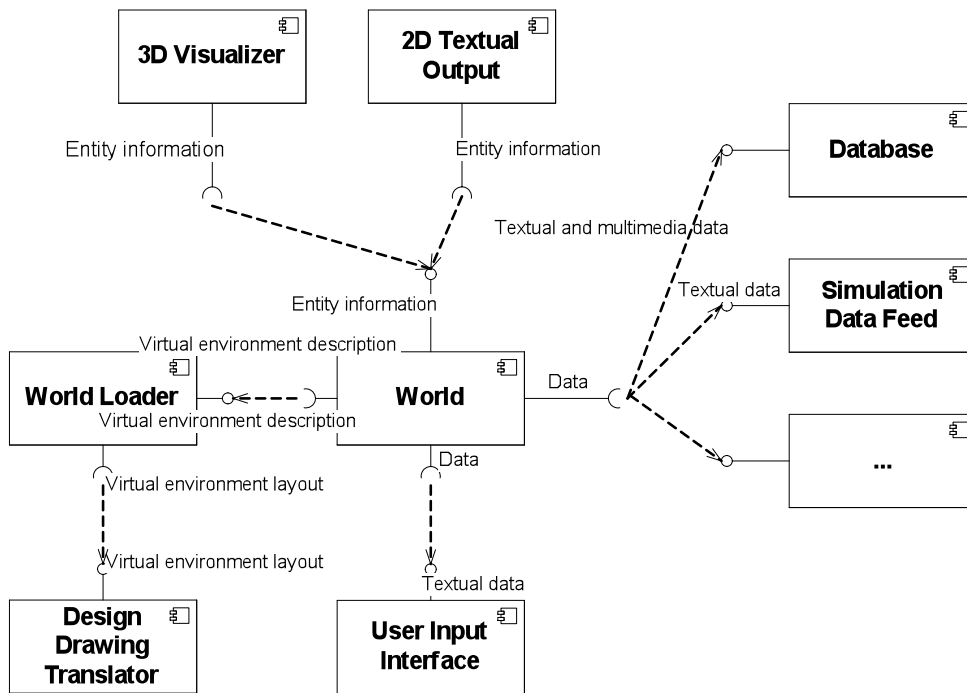


Figure 2 Component diagram of the Virtual Terminal

The environment is meant for two types of users: the container terminal CAD-designer or other actors involved in the design process (e.g. business analysts). The CAD-designer has the possibility to set a basis for the virtual environment by inputting the environment description. This level of detail of the drawing sets the realism of the future container terminal. The other users can input their documents, experiences and ideas into the system. They will have a framework set by the ontological structure present in the virtual environment, a context for each entity in the environment, and the possibility to act by querying information and adding annotations. The entities that contain information are highlighted so that they are easily identifiable.

3. Case study: an automated container terminal in the port of Rotterdam

The VT is currently being applied in the design of a large scale automated terminal in Rotterdam, which is expected to be one of the largest automated terminals in terms of scale and productivity. Because of this, major effort has to go in the assessment of novel types of equipment which are able to increase productivity e.g. automated guided vehicles, rail mounted gantry cranes. Moreover, multiple terminal layouts are considered in the design.

The design project has the characteristics of having many actors involved and a large design space. We will discuss these two characteristics and how the VT is being employed in this project. We will also present some preliminary informal evaluation of the VT.

3.1 Actors

Many actors are involved in the design project of the automated terminal:

- **Operational personal.** They have knowledge of terminal operations and are responsible for developing the operational specifications and operational framework.

- **Civil engineers.** They are responsible for all civil aspects of the terminal design. The main areas of focus: design of the quay wall and pavement.
- **Mechanical engineers.** They are responsible for the technical design of the equipment that is chosen in the design.
- **Simulation engineers.** Responsible for modeling the terminal design and evaluate choices in the design.
- **IT engineers.** Responsible for the design of the IT architecture and especially the terminal operating system (TOS).
- **Safety and environment team.** Responsible for all aspect concerning safety and environment.

Several external actors are also involved in the design project, besides the internal actors mentioned above, such as equipment manufacturers, potential customers, local governments and port authorities. Not all actors are involved in the entire process. The contribution of the actors also differs. The actors with the most frequent involvement are listed on top.

The VT is currently being used to support the design process. The following use cases were identified:

1. Creating a common framework of understanding. The VT is used during design sessions to study the impact of decisions.
2. Communication towards stakeholders. The VT is used to show what the designed terminal will look like in photorealistic 3D view.

A diagram of the design process supported by the Virtual Terminal is shown in Figure 3. We can notice how the complete environment (AutoCAD and 3D environment) allows all actors involved in the design process, to use an interface that supports their needs.

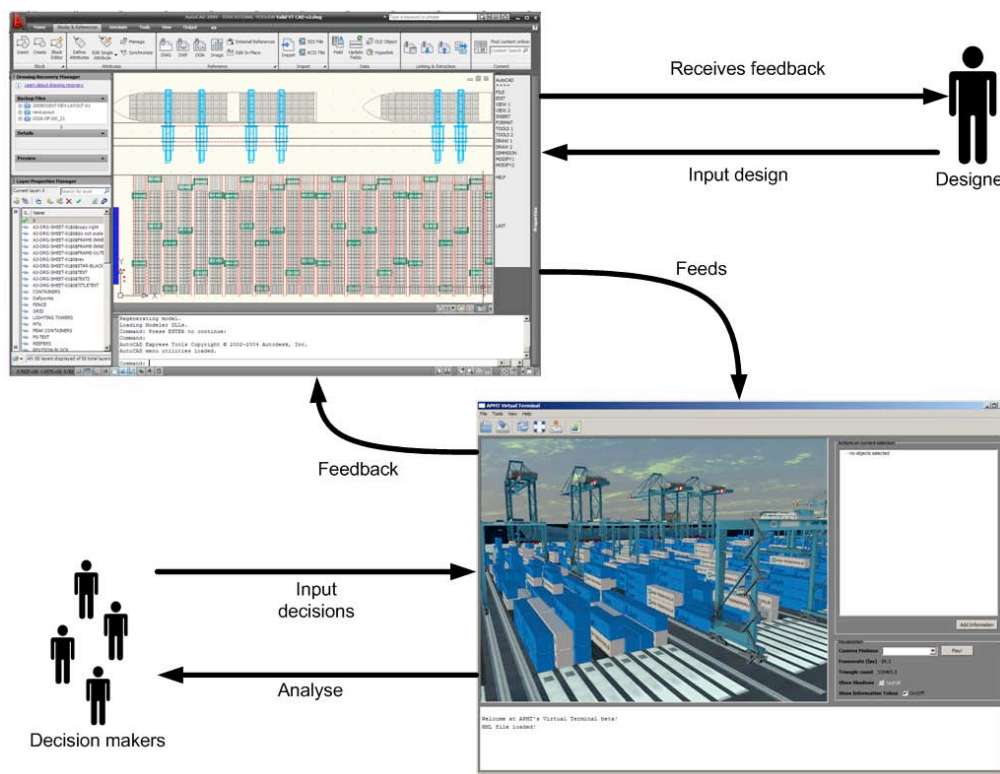


Figure 3 Using the Virtual Terminal in a design project.

3.2 Usage

As soon as a first rough design of the new terminal is established by the design team, a version of it is used for the VT. The initial drawings, which are drawn in AutoCAD, only sketch the first ideas on which much iteration follows. The conversion is based on the ontology which will later be used for structuring information. The ontology provides an overview of each entity which can possibly be present in an automated terminal and also shows the relations between these entities. Using this ontology in the CAD drawing, an almost direct translation can be made between complex CAD drawings and the virtual environment. Once this process, which is illustrated in Figure 4 (b), is done, the 3D virtual environment is ready to be enriched with information from the various actors involved in the design process.

Each object in the environment is selectable and can keep specific information which can be useful for decision making. The information which is deemed to be important is added to the environment so that everybody has access to it. An example of such an object can be seen in Figure 4 (a). In this example, a quay crane is selected and the available information is shown. This object contains information about the specification of the crane, the costs and estimated productivity results. Using the same functionality, annotations can be made which reflect ideas, remarks and questions on a particular item of the new container terminal. This improves communication between the actors.

During the following iterations on the design, the constructed virtual environment is used as a platform for discussion. The actors have achieved a shared understanding of the new terminal which makes it possible for everybody involved in the process, to achieve the required insight for making decisions.

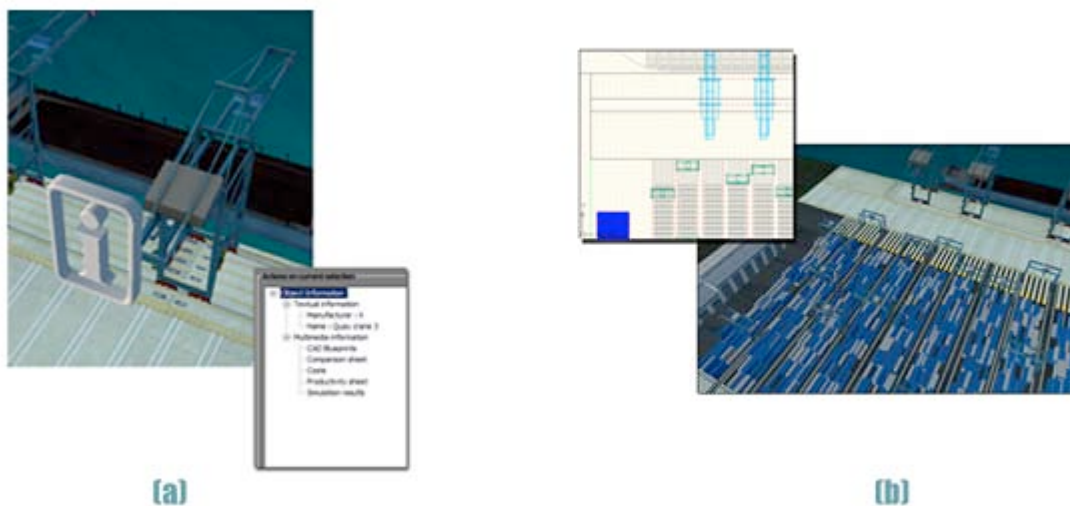


Figure 4 (a) Information can be added to objects in the environment (b) From CAD drawing to the 3D virtual environment.

3.3 Evaluation

The evaluation has been carried based on usability, usefulness and usage []. The usability has been measured using an ISO 9241 Part 10 (International Organization for Standardization 2006) compliant questionnaire (Gediga, Hamborg et al. 1999) during a design workshop with potential users. The usefulness and usage has been assessed qualitatively by semi-structured interviews with domain experts.

The first feedbacks from actors that have worked with the VT are very positive. First, the VT provides more insight by photorealistic images. Traditionally, 2D images and movies are used of terminal designs. The VT generates 3D images and movies of high quality. Furthermore, the VT is a virtual environment in which the users can freely move around. Secondly, the VT can be used before the terminal is implemented. Operators can be trained for their future job using the VT. Thirdly, the users also expect that the VT will have high value for the commercial aspects of the terminal. The VT can be shown to customers and used as a “selling” tool. Finally, the VT will be used for the communication of the design to port authorities, governments and other stakeholders. The design can be presented in an understandable format to all stakeholders.

To see how well the Virtual Terminals meets the requirements stated in section one, we interviewed members of the design team. The interviewees stated the following on the requirements based on their experiences in using the VT:

- The design team highly valued the high realistic and compelling 3D imagery provided by the VT. This is because of three reasons: 1) The use of CAD drawing, 2) photo realistic images of container handling equipment and 3) the use of logo’s of customers and suppliers and surroundings. The level of realism can be further increased by adding more moving elements in the VT.
- The VT supports the communication between both internal and external stakeholders. The VT was frequently used for communication to external stakeholders. These external stakeholders with little experience of automation still could understand the design easily.
- The VT contains sufficient details for decision making. The elements, e.g. AGVs and RMGs, are based on photos and design drawing of equipment suppliers. The VT contains therefore much more details than existing 3D visualization tools.

4. Conclusion and future work

The Virtual Terminal project has not yet been finished at the moment when this paper was written. We still would like to draw some conclusions from our research project.

Visualization presents a possibility to convey knowledge between different people which is important to gain insight into complex multi-actor environments. We presented the design of container terminals as such an environment and explained which difficulties arise when an automated mode of operation is desired. To tackle these problems, we have developed the Virtual Terminal which supports the design process of automated container terminals. We have seen how the Virtual Terminal is employed and how it helps the different actors in understanding the problem.

Future work on the Virtual Terminal will focus on the sources of information, information visualization and collaboration. As sources of information can be added to the Virtual Terminal, it becomes a challenge to present them all without suffering from information overload. Therefore information visualization techniques will be explored to tackle this problem. Collaboration patterns and best practices will be explored to improve the collaboration between actors involved in the design process. Secondly, future research will focus on applying the VT to the design of human operated container terminals. Although such design projects might be less complex than automated terminals, designers of human operated terminals have shown interest in the VT as well.

The final and most important question for our research project is: "Can we improve the design of automated container terminal by using the Virtual Terminal?". We can not yet answer this question at this moment. We have positive expectations, based on the feedback we got from users and domain experts.

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