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The VisPort Project: Visualization of Port Logistics

By Petros J. Katsioloudis and Ginger Watson

To achieve efficient knowledge transmission and understanding of port careers, a team of researchers . . . created a web-based tool that simplifies complex port logistics topics and strives to motivate students to become engaged in related careers.

The success of business, industry, and the military relies heavily on efficient air and sea transportation systems (Goldsman, Pernet & Kang, 2002). Efficient transportation using standard-sized containers generates logistical savings for businesses through economies of scale and flexibility in production and distribution. At the same time, cargo flow places significant stress on the U.S. transportation network. Major coastal container ports are currently operating near their maximum capacity, suffering from bottlenecks and delays in container movements. In the interim, the U.S. Department of Transportation (DOT) forecasts that by 2020, even at moderate rates of domestic growth, the international container trade will double from its current levels (Maritime Transportation System Task Force, 1999). Meanwhile, there is concern about the diminishing availability of skilled personnel that can operate in the wide variety of disciplines associated with port operations. Increasing cargo volume, combined with a shrinking workforce, could potentially create alarming situations in the future, hence the motivation to publicize to current students the breadth and benefits of port-related careers in the hope that these students will become tomorrow's skilled workforce. One possible first step to feed the pipeline of the port logistics profession is exposing young individuals to the world of port logistics and associated career opportunities.

According to Clark and Mathews (2000), visual technology enhances learning by providing a better understanding of the topic as well as motivating students. Visualization methods are widely credited for simplifying the presentation of difficult subjects as well as aiding cognition. Their use in the power of engineering education is enjoying significant growth (Idowu, Brinton, Hartamn, Nehard, Abraham, Boyer, 2006). To achieve efficient knowledge transmission and understanding of port careers, a team of researchers from Old Dominion University created a web-based tool that simplifies complex port logistics topics and strives to motivate students to become engaged in related careers. An issue such as containerization can easily be solved on a screen with the use of virtual maps and arrows instead of confusing directions on a piece of paper.

The VisPort tool combines a high-fidelity simulation of port operations with a rich, multimedia visualization of modern port careers aimed at promoting cognition of port logistics, improving higher-order thinking and problem-solving skills, and enhancing understanding of science, technology, engineering, and mathematics (STEM) topics related to port logistics, sustainability, and transportation disciplines (see Figure 4). The project emphasizes modeling and simulation of port logistics in order to provide a platform for introducing complex port logistics principles and problems that correspond to topics found in *Standards for Technological Literacy: Content for the Study of Technology (STL)* (ITEA/ITEEA, 2000/2002/2007) and national mathematics and science standards and engineering concepts. The project has the following specific goals:

- Provide a multimedia environment that allows students to learn about port careers, career ladders, required education, and most importantly, get a realistic sense for the day-to-day activities associated with each career.
- Provide a virtual-reality, firsthand experience associated with operating equipment and scheduling decisions associated with port operations.
- Provide a simulation of port logistics that can be used under instructor guidance to experiment with alternative equipment, operations, and algorithm selection while following the Engineering Design Process Model.
- Provide a tool that is usable to as wide a range of students as possible through a web-based interface.

In addition to the educational goal, we envision students in the future using the tool to identify potential problems found in port operations and using the engineering design process, as shown in Figure 1, to recommend improvements to port operations in instructional scenarios.

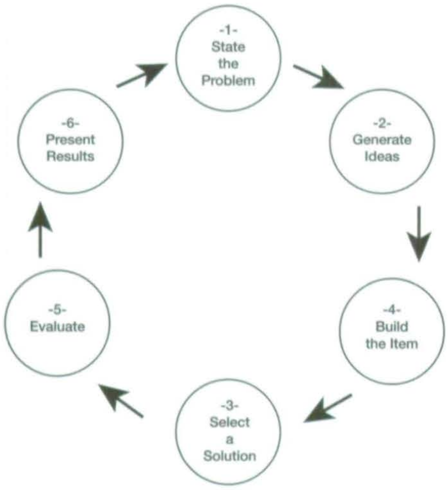

Figure 1. The Engineering Design Process Model may be described as a process used by engineers to help develop new products. The design process may include developing a new product or service or servicing a system to meet client or customer needs. Adapted from: www.nasa.gov/audience/foreducators/plantgrowth/reference/Eng_Design_K4.html.

Simulation Components

The simulation is designed to provide a firsthand experience in the daily life of a port by allowing a student to take over the responsibilities of a port worker inside the virtual world of the simulation. Achieving this requires a realistic simulation, as opposed to an animation, of the overall port operation. The tool is agent-based; the behavior of each entity in the simulation (e.g., equipment operators, workers, containers, etc.) is simulated separately to make it possible to introduce a live operator into the simulation while maintaining the overall simulation framework. For example, in an agent-based simulation, a container and a crane are simulated as two different entities. In order to pick up a container and move it, the crane agent must move the boom on top of the container, latch it, then move the crane to the destination, lower it and unlatch, all of it in continuous time. While the simulation is executing, it is possible to switch the Artificial Intelligence (AI) that controls the crane with the program's user so that the simulation can run autonomously or via the student's control. An opposing simulation methodology would be an event-based simulation in which the process of unloading a container would be an instantaneous event that takes place after a specific delay. In such a case, selectively replacing portions of the simulation to allow first-person participation is not possible.

In an agent-based simulation, the fidelity of the AI algorithms used by each agent in the simulation governs the realism of the overall simulation. It is also possible to run the simulation in real time or accelerated time modes. The accelerated mode is similar to time-lapse photography in which a two-hour period can be observed in a few minutes. This is particularly useful for learning the concepts of throughput and the impact of logistical delays.

Separate autonomous agents were designed for the ship captain, harbor pilot, crane operator, loading and unloading workers, container movement operators, truck drivers, security workers, and journeymen responsible for coordinating container movement. Subject matter experts were interviewed as to the processes they use to implement their jobs. The results were then programmed into each agent. The containers and equipment were programmed to behave according to realistic physics. For example, container-handling equipment speeds are programmed according to the actual equipment specifications, thus yielding realistic times for travel throughout the yard.

Logistics of Container Movement

The yard layout is depicted in Figure 2. A series of cranes transfer containers between the ship and the ground on the dockside, an area consisting of four lanes within which container-movement equipment can travel to deliver or pick up containers. In order to minimize the time the ship remains in berth, containers are quickly moved between dockside and the transfer yard, a portion of the overall port that acts as short-term storage for containers that have just been offloaded from the ship or are just about ready to be loaded onto the ship.

Figure 2. Shown here is a screen capture of computer simulation that models a sample port layout. The image is quite detailed in showing the travel lanes and loading area, container parking areas, gantry cranes, and the container ship.

Beyond the dockside, containers are moved between the transfer yard and the main storage yard, where they can remain for longer periods as necessary. The outgoing yard serves a purpose similar to the transfer yard; i.e., acts as a short-term buffer for containers that are to be loaded onto or have been delivered from trucks. Trucks from outside the yard drive onto the truck loading area where they can be loaded and/or unloaded and then depart without having to drive through the rest of the yard. This layout is just one of the many possible ways to organize a port yard and was picked for this project because of its relative simplicity, which nevertheless requires a wide range of realistic equipment, personnel, and container handling.

Agent logic was programmed using state machines. For each agent, a series of states are defined. While in a state, an agent performs a specific task; completion of the task or messages from other agents cause state transitions, which allow sequential task execution. As an example of this approach to programming agent behaviors, consider the straddle carrier, a flexible piece of equipment that is used to move containers from the dockside to the storage yard, rail, or trucks. Figure 3 illustrates a photograph of a straddle carrier or shuttle. This is a visual model used to represent it in the actual simulation software. The software architecture simulates the mechanical operation of the straddle carrier and the operator as two different agents. The straddle carrier operation is primarily a physics-based simulation that requires control inputs (throttle, steering, latch/unlatch commands) and simulates the movement of the equipment accordingly. The agent representing the human operator is programmed to act according to a series of task-driven states, as illustrated by the state transition diagram shown in Figure 4. This state diagram was generated by consulting with subject matter experts and converting the procedural description of the operator into a series of states that are amenable to computer programming.

Figure 3. Kalmar ESC 350 shuttle or straddle carrier is used to move loaded or empty shipping containers from one location to another on the dock area. Simulation activities require that the operator perform tasks the same as would be necessary on the job. Tasks such as steering, throttle control, latching, and unlatching of containers must be performed. (Photo courtesy of Cargotec.)

Specifically, during port operations, a straddle carrier operator is first assigned a specific job, which may involve working the dockside-to-transfer-yard loop, or the outgoing yard-to-truck-loading-area loop.

The straddle carrier operator starts at the idle state, during which he/she does nothing until a task is received. In

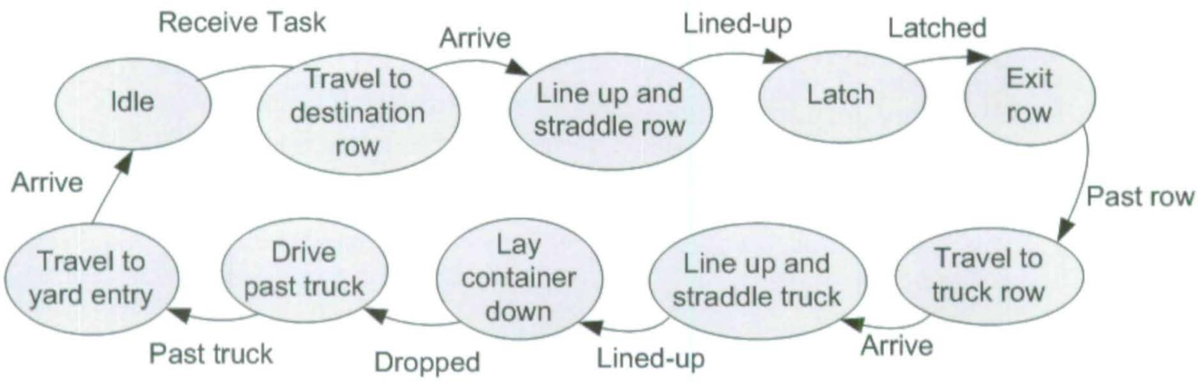

Figure 4. Straddle Operator State Diagram was developed by consulting with subject matter experts and converting the procedural description of the operator into a series of states that are amenable to programming in a computer.

the actual port, this is done through a radio or similar equipment that displays the task on a dashboard inside the cab. The task includes the container location, typically specified as a row, column, and layer. Once the task has been received, the operator drives the straddle carrier to the destination row by using any of the routes situated among the yard blocks. Upon arrival near the row, the operator will maneuver to line up the straddle carrier so it can straddle the row and reach the specific column, at which point he/she will latch the container (here for simplicity we assume it is the top container). Once the container is latched, the operator exits the row and then travels to a specific row in the truck loading area.

Straddle carrier operators typically perform a similar lining-up maneuver and straddle the truck, at which point the container is lowered on the truck bed. Finally, the operator advances past the track and then goes back to the yard entry point to wait for another task.

While at each state, the software simulating the agent generates control commands that are sent to the straddle carrier simulation, which in turn causes the vehicle to move accordingly. When a user requests to take over, the simulation simply removes the operator agent from the simulation and instead uses the commands from the human operator for guiding the vehicle.

The same approach is used for all autonomous agents involved in the simulation, although the only agents that can be replaced by the user in first-person mode are the gantry crane operator and drivers for three different types of container-handling equipment (straddle carrier, reach stacker, and port truck). The user can also choose to take on the role of a task scheduler and affect the assignment of resources or even micromanage equipment assignments sent to other agents in the simulation. (This mode is further described in the following section.) This design provides maximum exposure to the challenges involved in each career associated with employment within the port.

Scientific and Technical Visualization Curriculum

Based on visual learning, the Scientific and Technical Visualization Curriculum is designed to increase interest and understanding of geometry and science concepts; enhance capabilities to visualize in both two (2-D) and three (3-D) dimensions; improve presentation skills as applied to mathematical and scientific concepts; and result in higher competency in using the Internet for accessing, processing, and sharing information (Clark and Mathews, 2000). According to Clark and Wiebe (2000), the scientific visualization courses, with which the scientific and visualization curriculum is created, expose students to all of the major and conceptual areas associated with visualization and give them experience in a broad range of graphic techniques. Also through this curriculum, students use analytical and communication tools to gain better understanding and appreciation and the advantage of being able to apply the newly acquired skill—visualization—to further study the sciences, enter the workforce, or continue their study in a variety of other professions (Clark and Mathews, 2000).

The primary areas covered in the scientific and visualization curriculum courses include: basic design process, graphing, image processing, animation, simulation, presentation, and publication (Clark and Mathews, 2000). Although the Scientific and Technical Visualization Curriculum is developed as a vocational track, it could be integrated with other academic subjects. The concepts and information used throughout the curriculum can be integrated easily into mathematics, science, and technology education classes (Clark & Wiebe, 2000). By using simple and complex visualization tools, students can conduct research, analyze phenomena, solve problems, and communicate major topics identified in *Standards for Technology Literacy (STL)* as well as topics aligned with national science and mathematics standards (Wiebe, Clark, Petlick & Ferzli, 2004).

Ernst and Clark (2006) state that a technologically literate person understands and effectively communicates basic technological concepts, processes, and interrelationships with engineering, mathematics, science, and society. Developing the conceptual framework of the VisPort Project, as shown in Figure 5, illustrates the interrelationship between STEM, logistics, *STL,* modeling and simulation, and the VisPort model.

Communication technology is an integral component of technological literacy; therefore, modeling, visualizations, and presentations reinforce communication technology concepts (Ernst & Clark, 2006). Having strong communication concepts strengthens individuals' technological and scientific knowledge and abilities while providing students with an opportunity to gain a firm grasp of engineering principles behind the technologies (Newhagen, 1996). Visual and technical literacy maintain a significant role in successful knowledge and skill

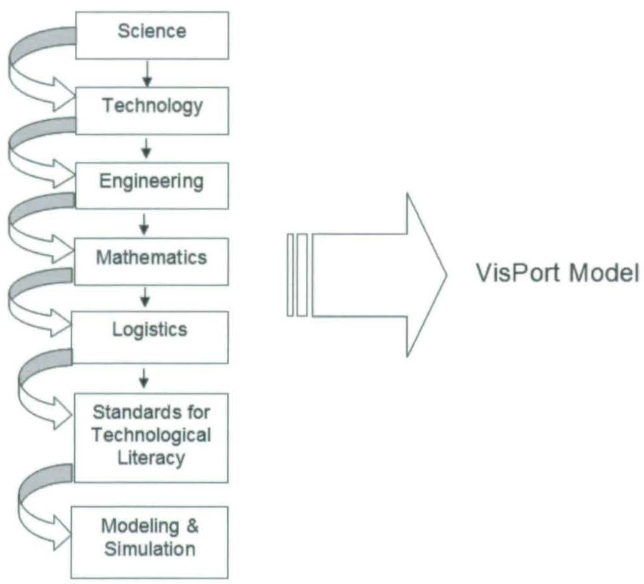

Figure 5. The conceptual framework of the VisPort Project as shown here illustrates the relationship between STEM, logistics, *STL,* modeling and simulation, and the VisPort model.

development in engineering and technology career paths (Wiebe, Clark, Ferzli & McBroom, 2003).

Design Initiative for Students

The activity described below will emphasize modeling, simulation, and application of port logistics in order to familiarize individuals and promote STEM-related careers. The project will emphasize modeling and simulation of physical systems in the port environments in order to bring real-world problems closer to students interested in pursuing STEM-related careers. The activity will include modeling and simulation of typical port logistics.

As a part of this activity, students will simulate port logistic applications, according to specifications and under guidance of the instructor, who in this case will serve as the head of the port authority. To be able to complete this activity, students need to be able to read technical specifications to determine different types of cranes and other types of transportation vehicles required in a port environment; therefore, the use of the VisPort software is necessary. Starting this activity, the students will receive instructions from the port authority, including the number and type of cargo ships that will be visiting the port. As a second step, they will lay out and mark a plan necessary to be distributed to crane and transportation vehicle operators. Once plan layouts are made, students will simulate the arrival of a cargo ship and coordinate the different applications under specific time and space constraints. Typically, logistic materials would consist of timers, signs, and other communication devices that can also be used so students can communicate efficiently and effectively with each other during the loading and unloading process. Once the operation is complete, the students should prepare a technical report identifying glitches and describing errors during the operation process and suggesting alternative methods of operation for future applications. Students should use at least one type of port logistics software during the plan-layout process. At the end of the activity, the instructor should evaluate the operation and specify positive and negative aspects of the simulated operation.

Upon the observation of several complex port logistic systems and by using the engineering design process (see Figure 1), students will identify potential problems found on the port site. Following the second step of the engineering design process, students will generate potential ideas and then, using modeling and simulation techniques (M&S), all potential ideas will be analyzed and tested to determine the best one. According to the results, the best idea will be chosen and executed during the port logistics activity. Upon completion of the activity an evaluation will take place for the students to draw conclusions and identify design flaws to be encountered.

Activities such as the one described above are easy to correlate with the technological literacy standards created by the International Technology Education Association (ITEA/ITEEA) in 2000. See Table 1 for correlations with *STL*.

Summary

A standards-based project, Visualization in Port Logistics (VisPort), is designed to promote the use of visualization and simulation among Grade 10-16 students to improve their higher-order thinking, problem-solving skills, and understanding of science, technology, engineering, and mathematics (STEM) topics as they relate to the port logistics, sustainability, and transportation disciplines. By experiencing the use of visualization tools, along with related content knowledge, the students gain a better understanding of complex port logistics principles and analyze, solve problems, and cover topics found in *Standards for Technological Literacy (STL)*, national mathematics and science standards, and engineering concepts. By the end of the 2010 fiscal year, the project team will create four units that will embrace areas such as transportation, sustainability, power, and energy. Since few existing curriculums specialize in the field of port logistics through the use of visualization tools, it is anticipated that the newly created units will embrace student learning and understanding in the STEM fields.

Table 1
Correlation with *Standards for Technological Literacy.*

The Nature of Technology	Technology and Society	Design
Std. 1: Students will develop an understanding of the characteristics and scope of technology.	**Std. 4:** Students will develop an understanding of the cultural, social, economic, and political effects of technology.	**Std. 8:** Students will develop an understanding of the attributes of design.
Std. 2: Students will develop an understanding of the core concepts of technology.	**Std. 5:** Students will develop an understanding of the effects of technology on the environment.	**Std. 9:** Students will develop an understanding of engineering design.
Std. 3: Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.	**Std. 6:** Students will develop an understanding of the role of society in the development and use of technology.	**Std. 10:** Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.
	Std. 7: Students will develop an understanding of the influence of technology on history.	

Note. Adapted from the International Technology Education Association. (ITEA/ITEEA) (2000). *Standards for Technological Literacy; Content for the Study of Technology.* Reston, VA: Author.

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