Optimal control of cranes

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Cranes in marine ports

Shipping containers revolutionized global trade and economy. Before it was introduced the on and off-load process was extremely slow and ships had to remain in port for weeks at a time. Nowadays, a large container ship can exchange in less than 24 hours.

To make it possible, different types of cranes operate and perform different tasks in marine ports, see Figure 1. Besides, some of the crucial performance indicators are:

- How fast a vessel is unloaded and re-loaded.
- Number of containers handled per yard area.
- How many containers per man-year are handled.

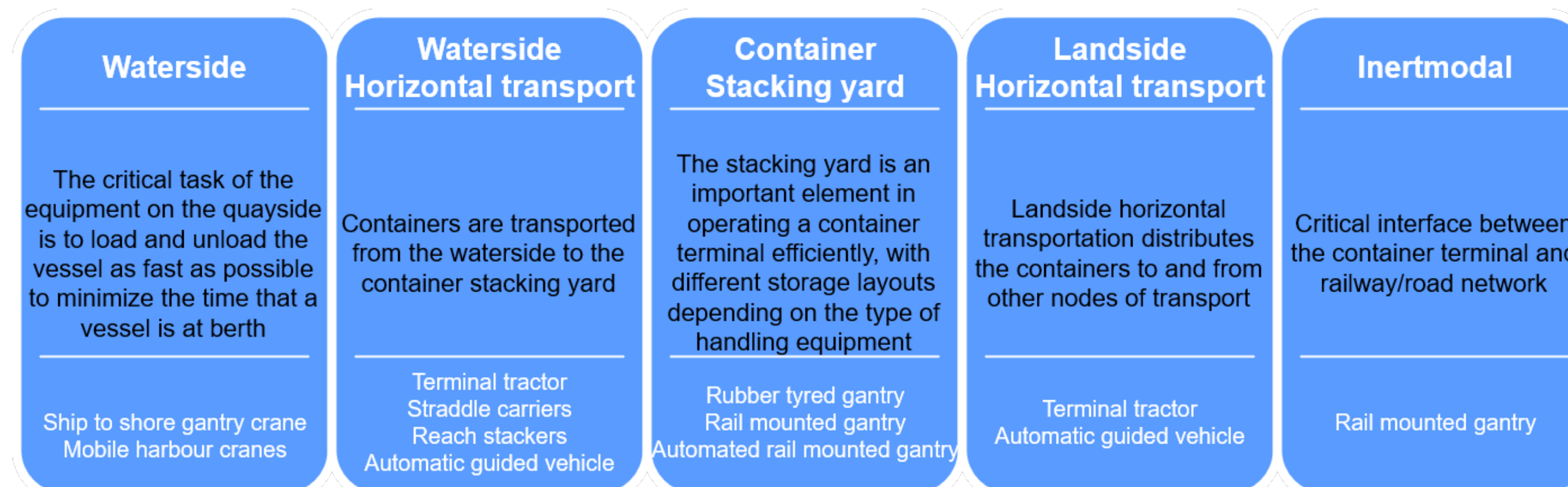| Waterside	Waterside Horizontal transport	Container Stacking yard	Landside Horizontal transport	Inertmodal
The critical task of the equipment on the quayside is to load and unload the vessel as fast as possible to minimize the time that a vessel is at berth	Containers are transported from the waterside to the container stacking yard	The stacking yard is an important element in operating a container terminal efficiently, with different storage layouts depending on the type of handling equipment	Landside horizontal transportation distributes the containers to and from other nodes of transport	Critical interface between the container terminal and railway/road network
Ship to shore gantry crane Mobile harbour cranes	Terminal tractor Straddle carriers Reach stackers Automatic guided vehicle	Rubber tyred gantry Rail mounted gantry Automated rail mounted gantry	Terminal tractor Automatic guided vehicle	Rail mounted gantry

Figure 1: Container handling in a terminal.

Among the several technical issues that must be dealt with to meet these goals, optimizing the containers handling time is essential. Therefore, fast and accurate automatic operation is necessary and will be the subject of this research.

Ship-to-shore cranes

Ship-to-shore cranes are used to load and unload shipping containers from vessels. With this aim, the container is locked to a spreader on its top by using a "twist-lock" mechanism. Thus, it is possible to lift, drive and lower it in the on and off-loading process using a trolley and ropes, driven by a machinery house and controlled in the operator cabin. Figure 2 shows the main components that enable the ship-to-shore gantry crane operation.

Figure 2: Ship-to-shore gantry crane.

Objective

Reducing the containers handling time in a terminal is necessary for more efficient operations in the port. From Figure 1 we also observe that loading and unloading the vessel as fast as possible is a key task to minimize the time that it stays moored. Which consequently improve the performance in terminal operations.

With this in mind, the research aims are:

- Develop a time-optimal controller for the on and off-load process.
- Perform experiments in a simulator.
- Implement the controller in a crane.

Figure 3 illustrates the loading and unloading process performed by a ship-to-shore crane on the quay. Figure 4 furthermore details the velocity v and pendulum's angle α profiles when the load (container) is driven by a trolley.
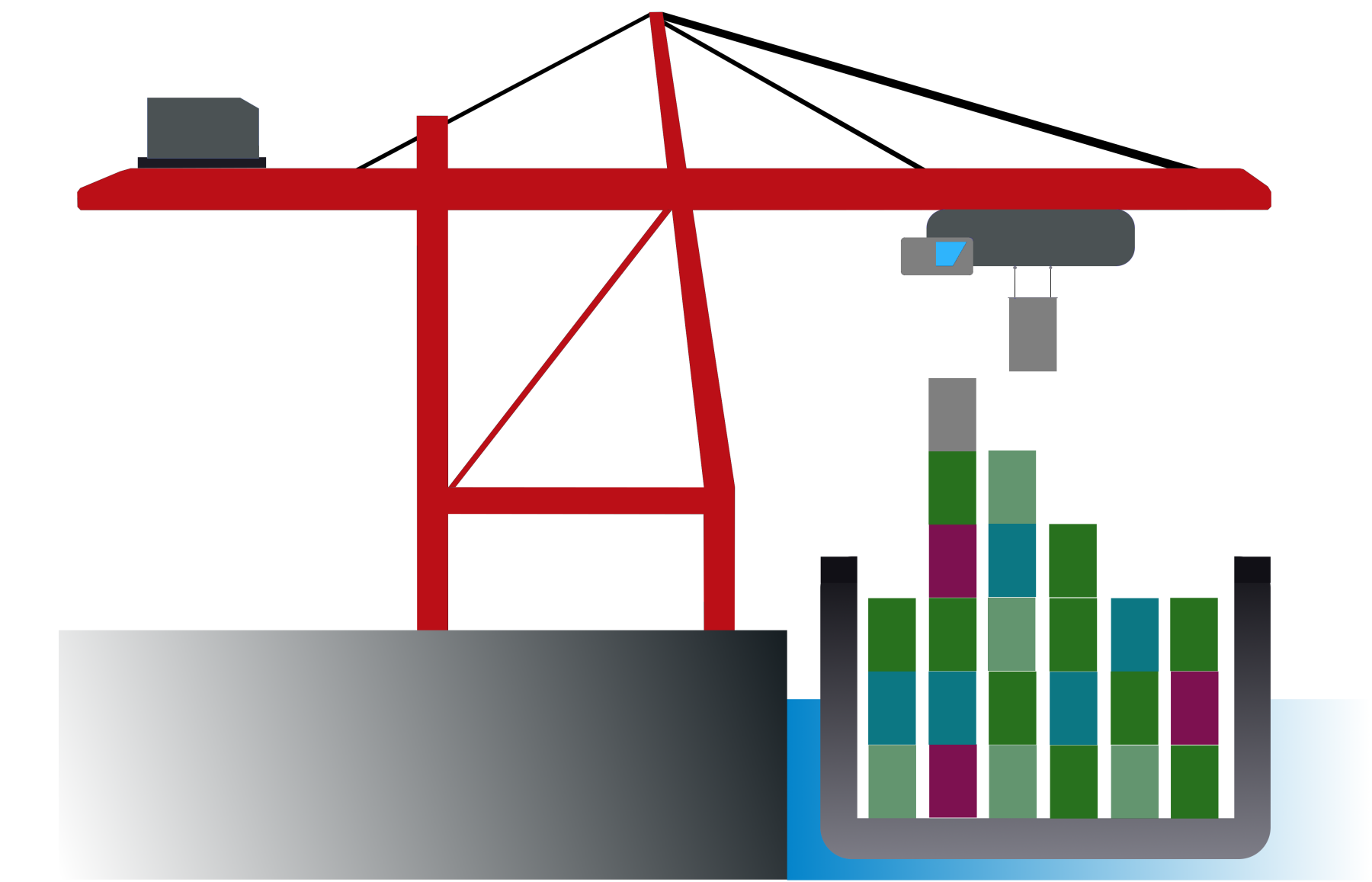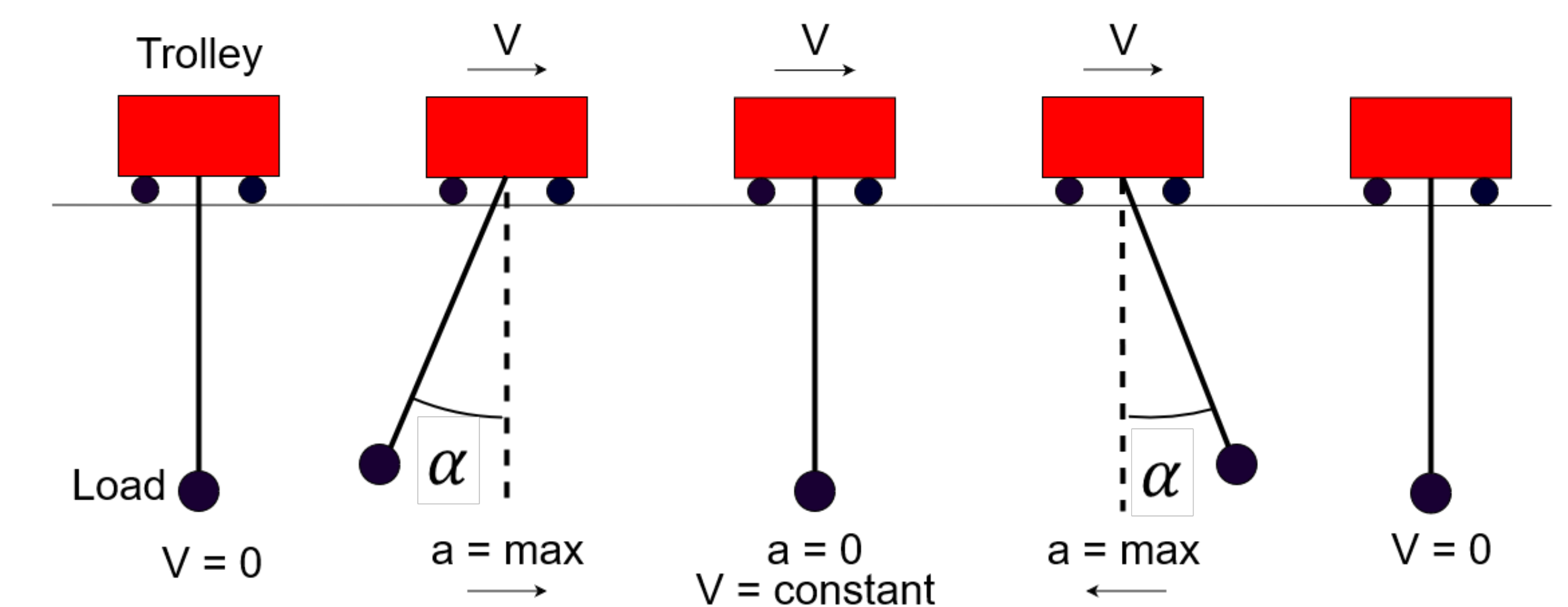

Figure 3: On and off-loading process.

Figure 4: Angle and velocity profiles during on and off-loading process.

Challenges

Finally, to the end of controlling the crane efficiently and safely, some challenges must be overcome:

- Hand over in the semi-manual mode must be treated.
- Failure safe solutions must be implemented.
- Wind, container mass and stack size must be considered.
- Enhance automation is the final aim.

Thus, this research can be beneficial and valuable in improving the efficiency of marine shipping.