Session Index

DYNAMIC POSITIONING CONFERENCE
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BASICS OF DP

Basics of Dynamic Positioning

Jon Holvik

Kongsberg Simrad Inc. (Houston)

Introduction

The paper will focus on the Basics of Dynamic Positioning.

Today there are two different system solutions available in the market:
1: DP Systems based on model control, and;
2: DP Systems based on PID regulator

The difference between these two solutions are that were the PID controlled based system is only able to correct the deviation after that it actually has happened, the model controlled based system can predict forward and thus apply corrections before any deviation has happened.
A model based system is more robust towards changes in system parameters and environmental changes.
A model based system may also stay on position for a short time (5-15 minutes, depending on environmental conditions) even after loosing all of it's reference systems.

The best and safest system to use is the model based system and the way this is done by Kongsberg Simrad is described in the following sections.

Basics of DP - Definition:

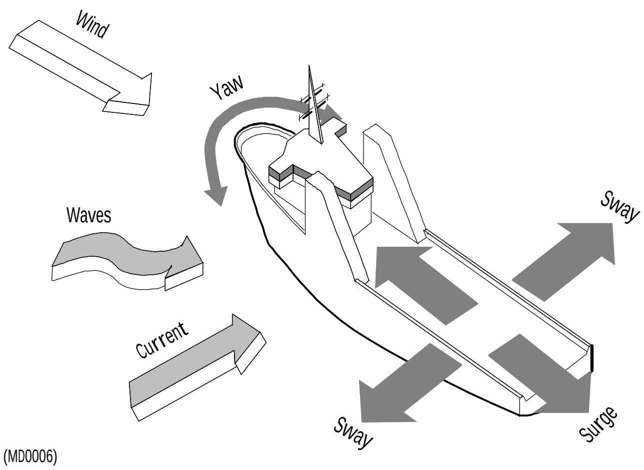
"A means of holding a vessel in relatively fixed position with respect to the ocean floor, without using anchors accomplished by two or more propulsive devices controlled by inputs from sonic instruments on the sea bottom and on the vessel, by gyrocompass, by satellite navigation or by other means."

Basics of DP (model based systems)

The Simrad Dynamic Positioning (SDP) systems are computerised systems enabling the automatic position and heading control of a vessel.
Set-points for heading and position are specified by the operator and are then processed by the SDP system to provide control signals to the vessel's thruster and main propeller systems. The SDP system always allocates optimum thrust to whichever propeller units are in use.
To control the vessel's heading, the SDP system uses data from one or more gyrocompasses, while at least one position-reference system (for example, GPS, microwave, hydro-acoustic, laser beam or taut wire) enables the SDP system to position the vessel.
Deviations from the desired heading or position are automatically detected and appropriate adjustments are made by the system.

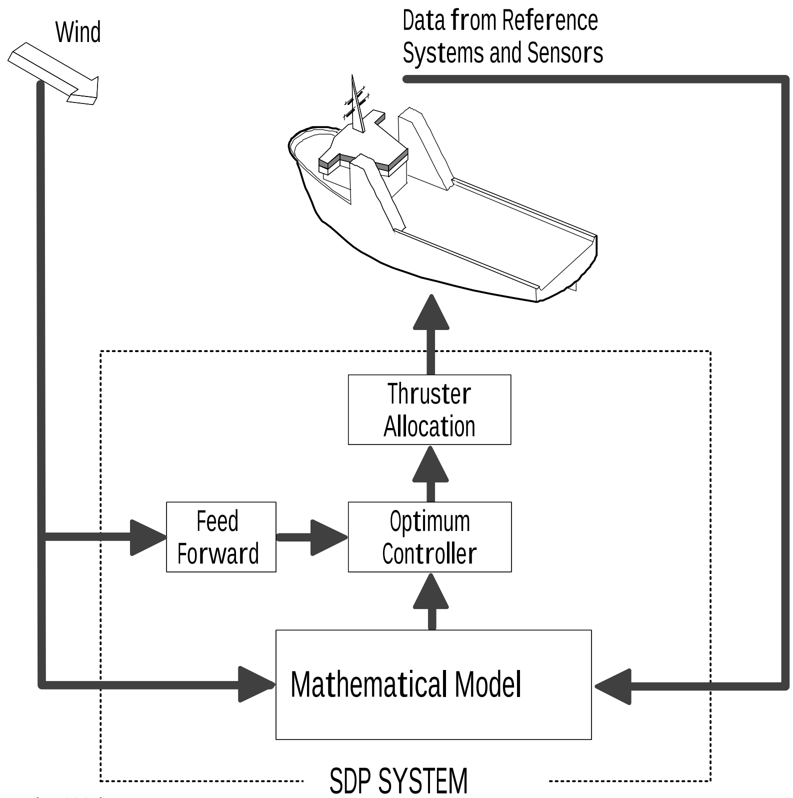
Basic Forces and Motions

A seagoing vessel is subjected to forces from wind, waves and currents as well as from forces generated by the propulsion system. The vessel's response to these forces, i.e. its changes in position, heading and speed, is measured by the position-reference systems, the gyrocompass and the vertical reference sensors. Wind speed and direction are measured by the wind sensors. The system calculates the deviation between the measured (actual) position of the vessel and the required position, and then calculates the forces that the thrusters must produce in order to make the deviation as small as possible. In addition, the system calculates the forces of wind, wave and water current which act upon the vessel and the thrust required to counteract them. The system controls the vessel's motion in three horizontal degrees of freedom - surge, sway and yaw.



Main Principles of Operation

The SDP system is designed to keep the vessel within specified position and heading limits, and to minimise fuel consumption and wear and tear on the propulsion equipment. In addition, the SDP system tolerates transient errors in the measurement systems and acts appropriately if an error occurs in the propulsion units.



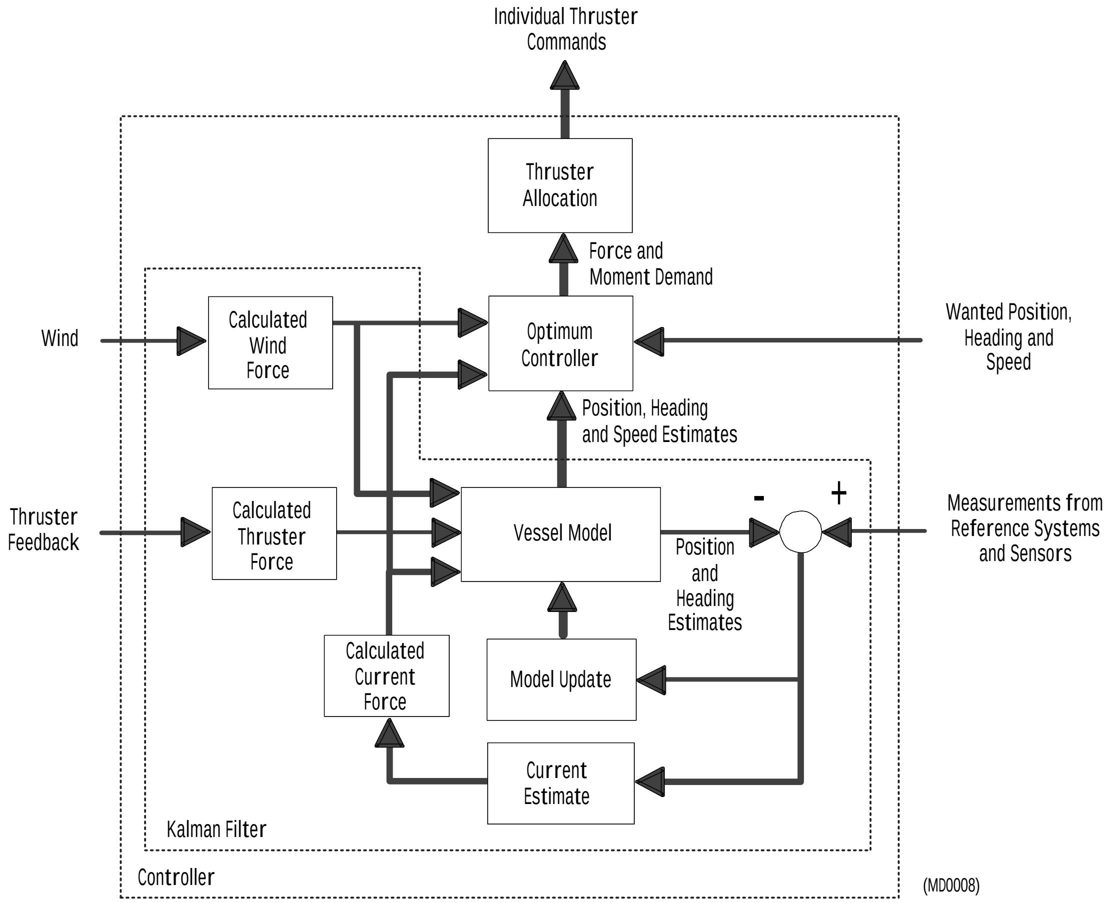
The main components in the SDP system are described in the following sections.

The Mathematical Model

The model is a mathematical description of how the vessel reacts or moves as a function of the forces acting upon it. The model is a hydrodynamic description, i.e. it involves the vessel's characteristics such as mass and drag. The design criterion for the model is an as accurate as possible description of the vessel's motions and reaction to any external forces.

The mathematical model is affected by the same forces as the vessel itself. Wind forces are calculated as a function of measured wind speed and direction, while thruster forces are calculated as a function of thruster/propeller pitch/rpm and direction.

The system incorporates algorithms for the estimation of sea current and waves, and the forces caused by these.



The main outputs from the mathematical model are filtered estimates of the vessel's heading, position and speed in each of the three degrees of freedom - surge, sway and yaw.
The mathematical model itself is never a 100% accurate representation of the real vessel. However, by using the Kalman filtering technique, the model can be continuously corrected. The vessel's heading and position are measured using the gyrocompasses and position-reference systems, and are used as the input data to the SDP system. This data is compared to the predicted or estimated data produced by the mathematical model, and the differences are calculated. These differences are then used to update the mathematical model to the actual situation.

The vessel's mathematical model and the Kalman filtering technique provide the following advantages:

- Optimum noise filtering of heading and position measurements.
- Optimum combination of data from the different reference systems. The system calculates a variance for each position-reference system in use and places different weighting on their measurements according to each system's individual quality (accuracy, stability, repeatability). Further information about the calculated variance and weighting can be found in the *Reference System and Sensor Data Processing* section.
- In the absence of position or heading measurements, the model provides an accurate "dead-reckoning" mode. This means that the system is able to perform accurate positioning for several minutes without position updates from any position-reference systems.

The Optimum Controller

The purpose of the optimum controller is to calculate the force which is to be exerted by the thrusters/propellers in order to keep the vessel at the required position or on the desired track. The result of this calculation is referred to as the **force demand** and consists of the following parts:

- Excursion Feedback
- Wind Feed Forward
- Current Feedback

These are described in the following sections.
It is also possible for an operator to use the SDP system's joystick and rotate controller to manually control the force exerted by the thrusters/propellers.

Excursion Feedback

Set-points for the heading and position, specified by the operator of the SDP system, are entered into the optimum controller. The differences between these set-points and the filtered position data, and the differences between required and actual speeds, are then calculated. These differences are multiplied by gain factors and the result is the force demand required to bring the vessel back to the wanted position and heading while also slowing down its movements.
This force demand consists of the following two parts:

- Restoring demand which is proportional to the deviation between the actual and required position and heading.
- Damping demand which is proportional to the deviation between the actual and required speed and rotation rate.

The gain factors are calculated and adjusted to optimise the control performance with minimum power consumption.

Wind Feed Forward

In order to counteract the wind forces as quickly as possible, the Feed Forward concept is used. This means that the SDP system will not allow the vessel to drift away from the required position, but counteracts the wind-induced forces as soon as they are detected.

Current Feedback

Even if forces are used to counteract the wind, stop the vessel's movements and keep it in position or along a predefined track, the vessel may still move out of position. This movement is due to forces that are not measured directly, such as waves and sea current. The system evaluates these forces over a period of time, and then calculates the thruster command signals that are required to counteract them.

Thruster Allocation

The optimum controller calculates the force demand in the surge and sway directions and the required rotational moment. These forces are then distributed to the various thrusters and/or propellers/rudders that are enabled by the system.
The optimal thruster allocation algorithm minimises thruster fuel consumption and the optimum controller reduces wear and tear.

Operational Modes

The vessel can be controlled in several different modes. The main difference between these modes is how the position and speed set-points are generated.

- The *Manual/Joystick* mode allows the operator to control the vessel manually using a joystick for position control and a rotate controller for heading control.
- The *Auto Position* and *Auto Heading* modes automatically maintain the required position and heading.
- The *Auto Area Position* mode automatically keeps the vessel within an allowed area and within allowed heading limits while using the minimum amount of power.
- The *Auto Track* modes (*low speed* and *high speed*) make the vessel follow a specified track described by a set of waypoints.
- The *Autopilot* mode enables the vessel to steer automatically on a predefined course.
- The *Follow Target* mode enables the vessel to automatically follow a constantly-changing position set-point.

In addition to these modes, various tailored modes have been developed to optimise vessel operation for a wide range of applications and types of vessels.

Reference System and Sensor Data Processing

Measurements of a vessel's position and heading at any point in time are essential for dynamic positioning.

Several different position-reference systems are normally used with the SDP system. The first position-reference system selected and accepted for use with the SDP system becomes the reference origin (the origin of the internal coordinate system).

As several different position-reference systems may be used, the SDP system carries out a series of tests on each of these systems to check whether their position measurements are accurate enough for use.

If the tests show that some measurements are outside acceptable accuracy limits then these measurements are disregarded by the SDP system.

In addition, the SDP system calculates a **variance** for each of the position-reference systems in use. The variance of a position-reference system is a filtered value based on the squared difference between the measured position and the estimated position from the mathematical model (mean square value). This variance is used in the variance test (described below) as well as for calculating a **weighting factor**.

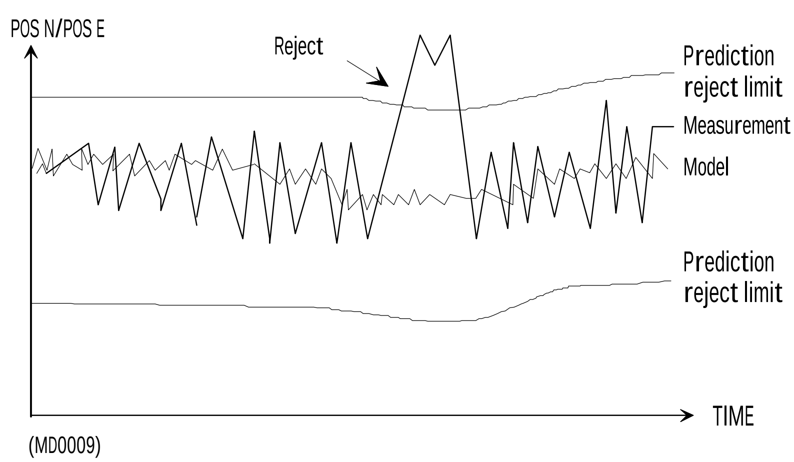
The SDP system uses this weighting factor to assign weightings to the position-reference systems. The higher the system's variance, the lower its weighting factor. Most emphasis is placed by the SDP system on the reference system with the highest weighting factor while least emphasis is placed on the one with the lowest weighting.

In order to calculate whether or not the position measurements from a position-reference system are accurate, the following tests are carried out by the SDP system:

- Prediction Test (short-term accuracy assessment)
- Variance Test (long-term accuracy assessment)
- Median Test

Prediction Test (short-term accuracy assessment)

The prediction test detects sudden jumps in the measured values and immediately rejects those that lie outside the limits:

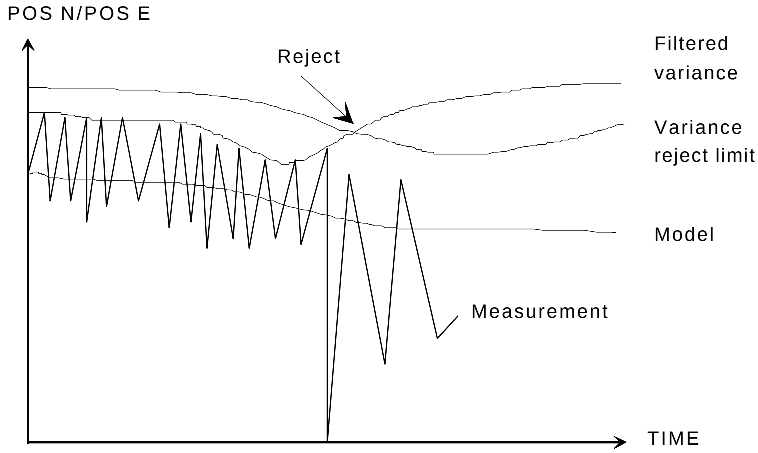


The prediction reject limit is established as a function of the estimated position in the mathematical model and the current accuracy of this estimate.

The latter depends on the overall variance of the reference system readings.

Variance Test (long-term accuracy assessment)

The variance test detects if the variance in the measured values exceeds the reject limit. The variance reject limit is continuously calculated and is based on the variance of the position-reference system with the lowest variance.



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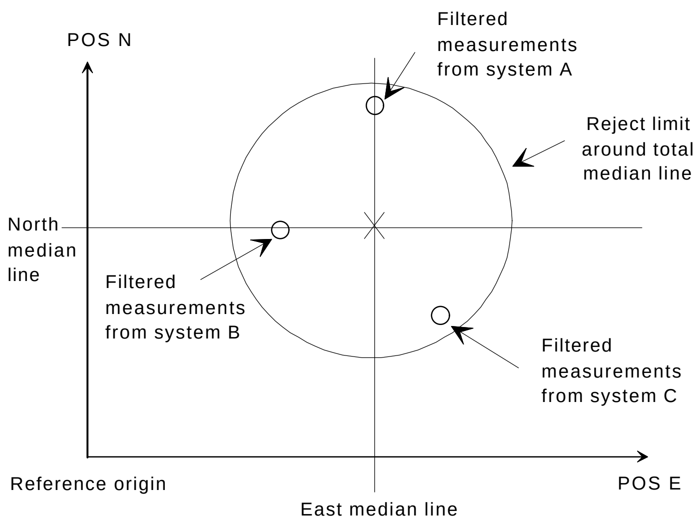
Median Test

When three or more reference systems are in use, the median test detects when measurements from one reference system differ from the others. In this test, measurements are used independent of the mathematical model. Therefore, slow drift in systems, even in systems with low variance, will be detected by this test.



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For all three tests, alarms are reported to the operator when the defined limits are exceeded. Before the tests are carried out, a received position-reference signal is checked for validity.

Conclusion

Dynamic Positioning systems have improved significantly over the past years, but will in the future have to be developed even more to ensure safe operation of deep water applications.
In addition we also have to remember that the DP system is only as good as the weakest point in the chain, meaning that the control systems for Thrusters, Generators, Power Management, Sensors and Reference Systems have to have a certain standard and accuracy in order to be able to Position a DP -Vessel accurate and safe.