Chapter 1

Introduction

1.1 General Introduction

A prototype onboard ship routing system is a desired tool for ship owners and ship masters. Such a tool enables them to optimize the route resulting in financial benefit of some form. Ship routing involves the solution of optimal control problems in the context of meteorological navigation of ships, and is concerned with finding a most suitable path between source and destination in an open sea by considering certain criterion (e.g. transit time, fuel consumption, damage to cargo or comfort of passenger). Determination of an optimal route of a ship in a sea-way helps in the reduction of voyage cost as well as ensures safety during voyage. Modern decision support systems (DSS) can provide a wide range of capabilities. Computerized systems can support decision tasks like information gathering, model building, collaboration, alternative evaluation and decision implementation. Decision support is presently found to be increasingly integrated with business processes. Ship-weather routing capability is also a form of decision-support system. From ancient times, a captain has been selecting route considering the weather characteristics such as prevailing wave, wind and current status in specific season and area. To predict a suitable route that will result in eventual financial saving, it is necessary that weather data in the cruising area is available in sufficient detail and that there is adequate knowledge on ship behavior in waves.

Broadly, optimum ship routing can be defined as the selection of an optimum track for an oceanic voyage by the application of long-range predictions of wind, waves and currents to the knowledge of ship's response to these variables.

When a ship sails in the open sea, it encounters various environmental disturbances such as wind, wave, current, ice, fog etc. which effect its safety and operating performance. For the merchant vessel, these effects cause changes in ship operating economy, while for military application, the vessel's tactical effectiveness may be influenced.

To derive an optimal trajectory of a ship route, it is therefore an essential pre-requisite to know the sea-state condition, and the behavior of the ship in waves. In the simplest case, the behavior of the ship could be represented by loss of speed due to the wave-field. Time of travel over a fixed distance is inversely proportional to average velocity. Thus, using inverse of velocity as the weight function for a given path in a suitable path-optimization algorithm, the minimal time path for a given ship could be found.

1.2 Objective of the Present Work

In this present work, an attempt has been made to formulate a mathematical model to determine an optimal path for ship routing by taking real time weather information and ships data. This problem is also referred to as weather routing or ship weather routing. When defined as an optimization problem, ship routing is concerned with the choice of the most suitable strategic trajectory or route and the corresponding control options from the voyage origin to destination so that a desired objective function or performance index is optimized.

Sea route optimization of a ship considers optimization of certain factors associated with it such as:

- minimum transport time (which is related to the speed loss in seaway)
- minimum fuel cost (which is related to the added resistance in waves)

- minimum damages to the structures (minimizing wave-loading on the hull including, fatigue loading, minimizing local peak pressures, etc.)
- minimum motions for specific operation (e.g. minimum slamming/deck-wetness/propeller emergence, all of which are related to minimum relative motion in vertical plane, minimum roll motions, etc.)
- fixed time of arrival

More than one of the above criteria may be important and relevant. As an optimization problem, it may be necessary to select the most suitable criterion as the function to be optimized while the other criteria can serve as system constraints. For commercial applications, usually the most important objective function for the ship routing problem is to minimize the total voyage cost. The voyage cost may consist of two parts, operating cost (mainly fuel cost) and terminal cost (cost of delay at the destination). The system constraints in this case can be based on some specific set of ship motion seakeeping criteria chosen to ensure crew/passenger comfort and to avoid damages to cargo and ship. From this viewpoint, the problem will be to find the ship route and the corresponding controls such that the total voyage cost is minimized while all the constraints based on the ship motions are satisfied. In the present work, because of the difficulties in handling complex functional forms, the model has been restricted to the minimization of transit time rather than that of cost. This minimum voyage time criterion however is quite a practical choice for commercial cargo vessel operations.

1.3 Outline of the Thesis

An algorithm for the optimal ship routing track is developed in this thesis. The present chapter, Chapter 1, has provided a brief introduction to the general ship-routing problem and its necessity. Chapter 2 provides review of literature. Chapter 3 describes the basic theoretical and numerical aspects on wave modeling and ship performance in waves. From the perspective of optimization theory for the present ship routing problem, various optimization principles are discussed and finally the adopted algorithm, the Dijkstra's algorithm, is presented in Chapter 4. In Chapter 5, several relevant and important aspects necessary for practical application of the developed algorithm by ship operators have been considered, and suitable implementation of these aspects in the algorithm is described. These include consideration of non-navigable waters, voluntary speed reduction, consideration of wind and current fields, storms etc. Also considered how a dynamically evolving wave field where the wave conditions continuously change with time can be taken into account. Concluding remarks and scope of further work are described in Chapter 6.