Case-Based Stowage Planning for Container Ships

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Abstract
In spite of the intensive usage and advancement of information technology, its support in stowage planning today is limited to the visualization of the process of planning and to calculation of the state of ship concerning stability, strength or hazardous cargoes check. The core process of planning is still performed manually. The growing size of container ships and their tight schedule imply the need for a reliable tool which reduces the burden of human planner. The knowledge for creating a stowage plan is imprecise, subjective and changing over time. It is hardly possible to extract it as an array of mathematical formulas or what-if rules. The proposed method is based upon the case-based reasoning methodology. The casebase storing past planning sessions, contains the knowledge on planning. The method is capable of learning. A new stowage plan is made by remembering how a similar past stowage planning problem was solved.

Keywords: stowage planning, container ships, fuzzy set theory, case-based reasoning

1. INTRODUCTION

A stowage plan is a two dimensional diagram of the positions of containers on board a container ship. Increasing size of container ships and the tight schedule of ship operations become a pressure for the stowage planner. That situation is prone to human error.

Before the arrival of a ship, the planning department receives a container loading list and the expected arrival conditions of the ship. The former contains details of containers to be loaded, which involves imprecision and inaccuracy. In many cases even until two hours *before the completion of loading*, the container loading list (CLL) is still changing, i.e. additional cargoes to be loaded or cancellations.

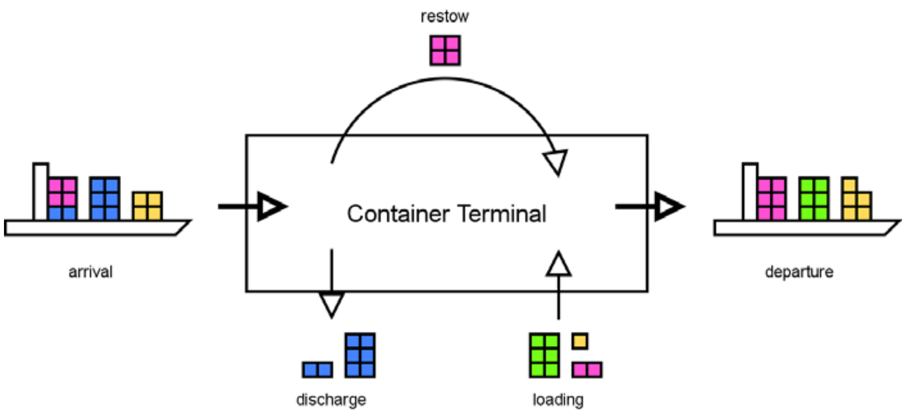


Figure 1. Stowage planning and restows

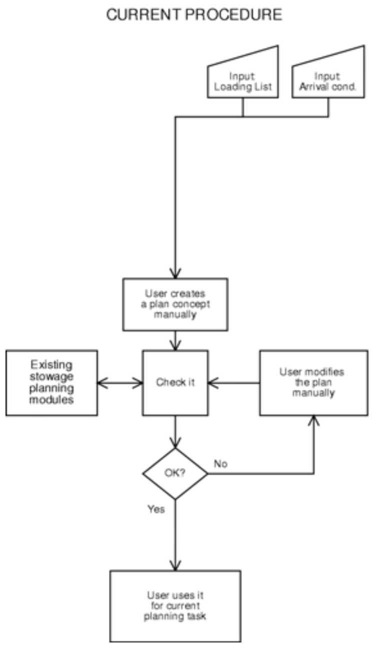


Figure 2. Current stowage planning procedure

To perform stowage planning tasks, computers become indispensable. The planner receives the cargo information (CLL), and he creates a stowage plan concept manually. Then he enters the plan concept into the stowage planning program, and lets the program check on aspects such as stability, strength and hazardous cargoes using available modules.

As the size of container ships increases and their schedule becomes tighter, the pressure for the planners is increasing. The quality of stowage plan is at stake which might result to more restows, see Figure 1, or in the worst case it might lead to a serious marine casualty.

Current stowage planning software provide checking modules, showing the state of ships or cargoes, e.g. the ship is stable or not, but they do not provide any assistance of what-to-do if the stability criteria are violated. The core process of planning namely constructing a plan concept is still carried out manually [5], see Figure 2. Over the last three decades there are over 30 works documented aiming at (semi-)automating the process of stowage planning [2, 4, 6, 10, 12]. The methods used can be classified into four groups, i.e. probability-based simulation, heuristic modeling, mathematical modeling, rule-based systems and genetic algorithm.

2. FOUNDATIONS

Planning is a search problem [3] and this task can also be viewed as an interplay between objective and constraint functions [7]. The planner seeks the appropriate slots for containers to be loaded. The objective is that the number of restows must be as low as possible, since it means literally extra cargo handling costs beside other fixed costs as a result of the prolongation of ship's stay at berth. Most planning tasks can be viewed as a routine, a repetition of similar problems, since a ship trades the same route for a certain period of time. Only a minority of planning problems can be viewed as completely new or unique, which need extra attention. Route deviation, opening a new service, employment of a new ship belongs to this minority group of planning problems.

Planning is a learning process, and it is knowledge-intensive [8]. A skilled planner knows typical cargoes for a ship planned a particular route. From experience he knows the allocations of certain slots or holds for each specific situation, i.e. route and season. Since every situation is different and this changes over time, it makes it hardly possible to translate it into formulas or rules. The degree of difficulty of stowage planning depends upon routes of the ship and preferences of ship operator. Every route involves its own degree of cargo heterogeneity, time and geographical constraints which may fluctuate seasonally or change over time.

Planning is subject to subjective preferences [9]. The sales department usually accepts special requirements of important clients for stowing their containers in certain slots, whilst otherwise those containers would have been stowed elsewhere. And this will subsequently be instructed to the stowage planning department.

Finally stowage planning is a chained process. A plan made for a port of loading has consequences to the plans and planning tasks in the ports of loading to follow.

3. STRATEGY

The strategy chosen is not to develop a complete plan straightly, rather it is intended to develop an almost finished plan, which are then modified until the plan is finished.

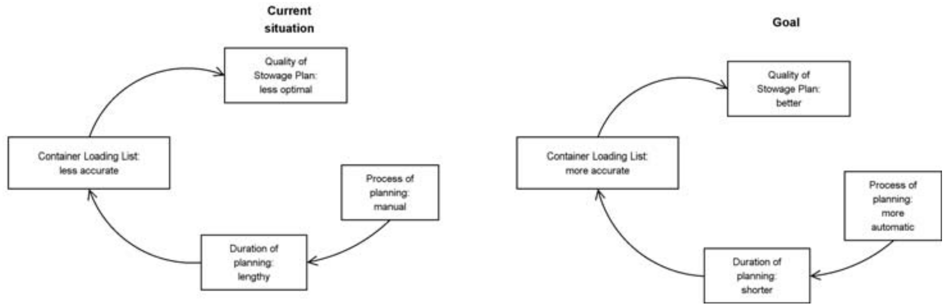


Figure 3. Strategy

The strategy is to cut the planning duration, so that the quality of cargo information will improve, see Figure 3. This will in turn improve the quality of stowage plan produced. The method is designed to respect the subjectivity aspects of planning. It is realized by proposing the planner few planning concepts, and letting the planner to choose one of the proposed concepts or even to reject them at all and let him start the planning process from scratch.

4. CASE-BASED STOWAGE PLANNING

4.1. Procedure

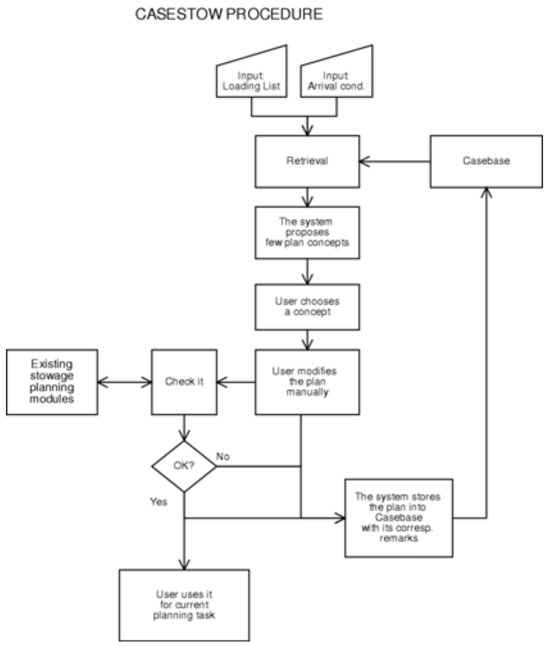


Figure 4. CASESTOW procedure

Using the Case-Based Stowage Planning system, abbreviated as CASESTOW, a stowage planning task is performed by remembering how past similar planning tasks were performed, based on the Case-Based Reasoning (CBR) methodology. The underlying concept of CBR is that an average actual problem which possesses some similarity with a known problem, is likely to have a similar solution.

The knowledge in the system is stored in the casebase, where cases are systematically stored. Viewing the planning process as a problem-solving session, a case is viewed as an accomplished stowage planning session. A case contains the planning problem, and its solution, i.e. departure stowage plan. Since a planning session may succeed or fail, its product can be remarked as a poor or a favorable plan. This useful experience can be used to expedite the planning process; a good case can guide the planner towards a solution, and a poor case warns the planner to avoid a plan concept or to use it with care.

A problem is the input of the process of planning described as a tuple[1] consisting three elements:

problem = < *stowage plan prior to loading, container loading list*>

The solution is the produced stowage plan:

solution = <*departure stowage plan* >

Every planning session may produce stowage plans of a variety of quality, from a poor to an excellent one. This information is stored as a comment on the plan:

remark = < *comments on departure stowage plan* >

A case is a finished planning session, defined as a tuple consisting three elements:

case = < *stored problem, stored solution, stored remark* >

A new stowage planning task, an actual problem, is called query:

query = <*actual problem*>

The CBR methodology consists of four steps [1,11]:

1. Retrieving the most similar cases
2. Reusing the chosen case(s) to solve the problem
3. Revising the proposed solution if necessary
4. Retaining the new solution as a part of a new case.

The CASESTOW procedure is shown in Figure 4. After receiving the input, i.e. loading list and prior-to-loading conditions of ship, the program searches for similar cases stored in casebase.

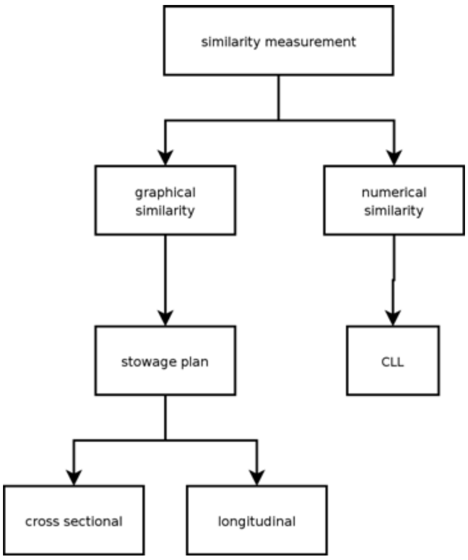


Figure 5. Similarity measurement

The similarity between a case, taken from the casebase, and the query is calculated. The similarity measurement comprises two types of measurements, numerical and graphical, see Figure 5. In the numerical similarity calculation the similarity between

[1] A tuple is a data object containing two or more components; it is also known as a product type or pair, triple, quad, etc. Source: *The Free On-line Dictionary of Computing, © 1993-2004 Denis Howe*

the actual CLL and a case’s CLL is computed. To perform this calculation, a trapezoidal fuzzy membership function is used, see below and Figure 6.

$$
\text{sim}_{\text{attribute}}(\text{query, case}) = \begin{cases} (a-x)/(a-b) & \text{when } a \le x \le b \\ 1 & \text{when } b \le x \le c \\ (d-x)/(d-c) & \text{when } c \le x \le d \\ 0 & \text{otherwise} \end{cases}
$$

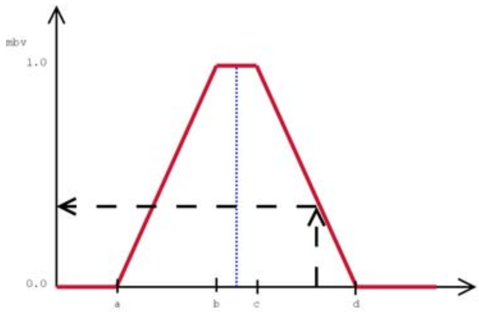


Figure 6. Trapezoidal fuzzy membership function

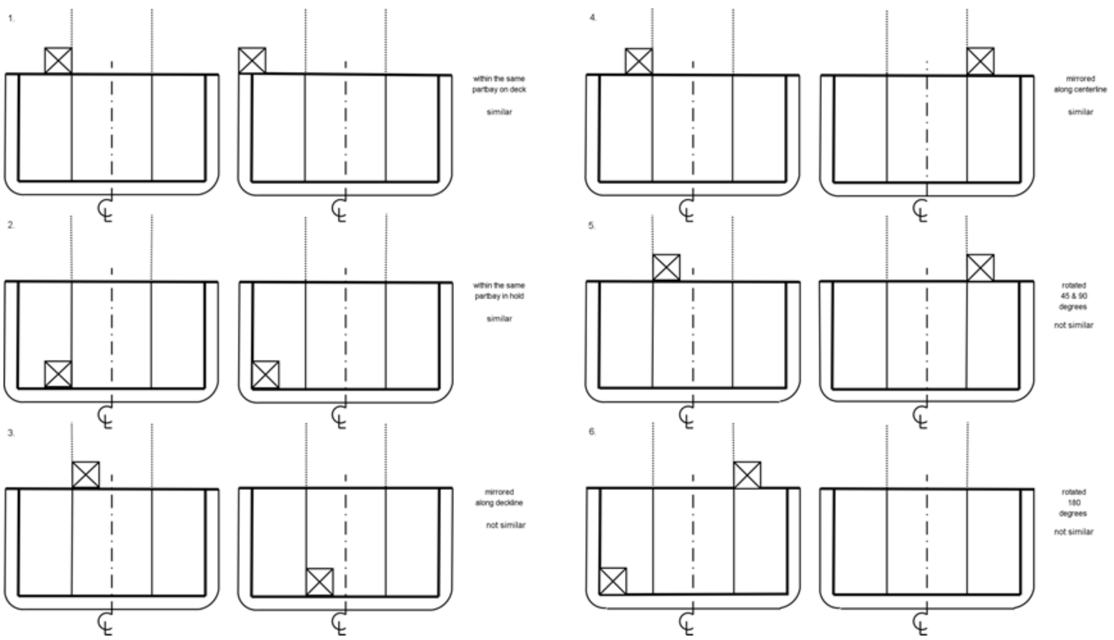


Figure 7. Cross-sectional criteria for graphical similarity measurement

During the graphical similarity calculation the similarity between two stowage plans is computed. To implement this graphical similarity calculation, the rotational, symmetrical, and neighborhood properties of a plan are taken into account. The computation considers two directions, cross-sectionally and longitudinally. The cross-sectional graphical similarity criteria are shown in Figure 7.

The system indexes similar problems and proposes them to the planner. The planner chooses one of them, called the basic plan. Guided by the solution concept of the basic plan, the planner constructs his plan. He may copy the chosen plan concept and then modify it. After completing a planning session, the stowage plan produced is commented with remarks and then stored in the casebase. This new case can be used immediately in the next stowage planning session. This step is the learning part of

CASESTOW.

5.2. Experiments

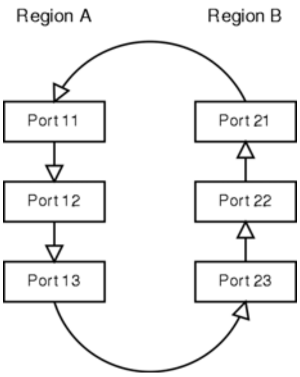


Figure 8. Route

A container ship trades between two regions, each consists of three ports, see Figure 8. For presentation purposes, the ship is simplified as a ship consisting of one bay only. It is assumed that during loading, no container is being or going to be discharged. The container loading list (CLL) and the stowage plan prior to loading are input.

Cases containing similar problems are proposed to the planners, see Figure 9. Every case contains CLL, stowage plan at arrival, and the departure stowage plan and remarks. The planner chooses a plan concept which meets his solution concept and preferences, see Figure 10.

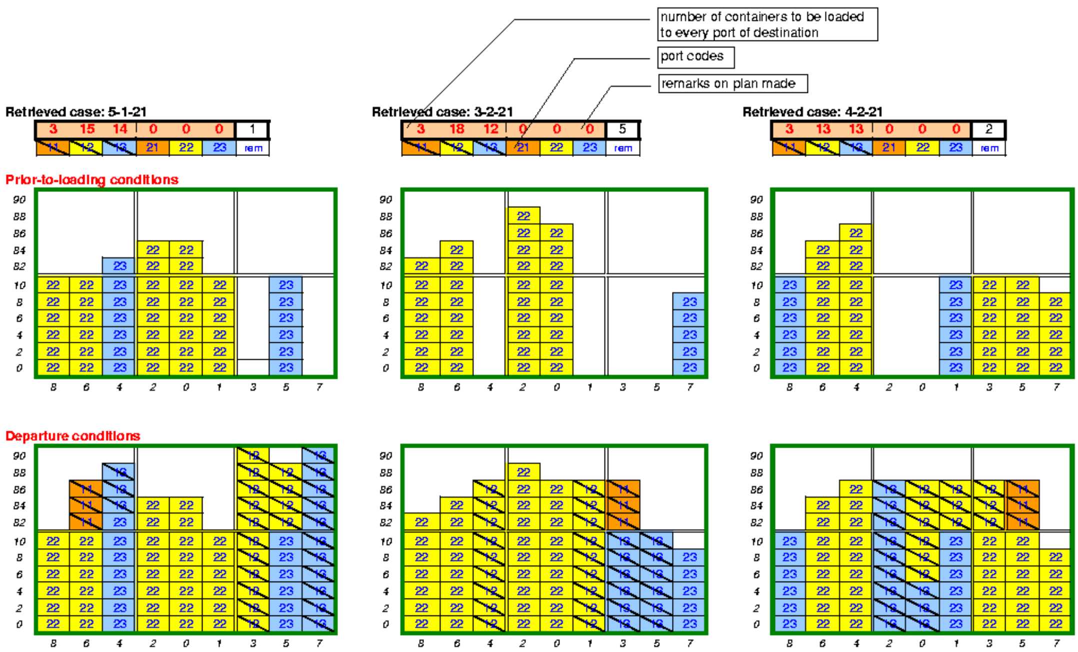
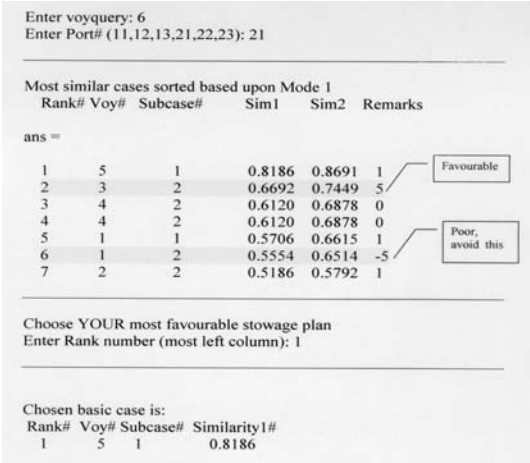


Figure 9. Retrieved cases



Enter voyquery: 6
Enter Port# (11,12,13,21,22,23): 21

Most similar cases sorted based upon Mode 1

Rank#	Voy#	Subcase#	Sim1	Sim2	Remarks
1	5	1	0.8186	0.8691	1
2	3	2	0.6692	0.7449	5
3	4	2	0.6120	0.6878	0
4	4	2	0.6120	0.6878	0
5	1	1	0.5706	0.6615	1
6	1	2	0.5554	0.6514	-5
7	2	2	0.5186	0.5792	1

ans =

Favourable

Poor, avoid this

Choose YOUR most favourable stowage plan
Enter Rank number (most left column): 1

Chosen basic case is:

Rank#	Voy#	Subcase#	Similarity1#
1	5	1	0.8186

Figure 10. An example of a session

The solution concept chosen is applied to the actual problem. To create a departure stowage plan, the planner modifies the prior-to-loading stowage plan guided by the concept; considering important aspects such as uncertain future cargo flow and specific clients' preferences. Therefore the same plan concept may lead to more than one final departure plans, see Figure 11.

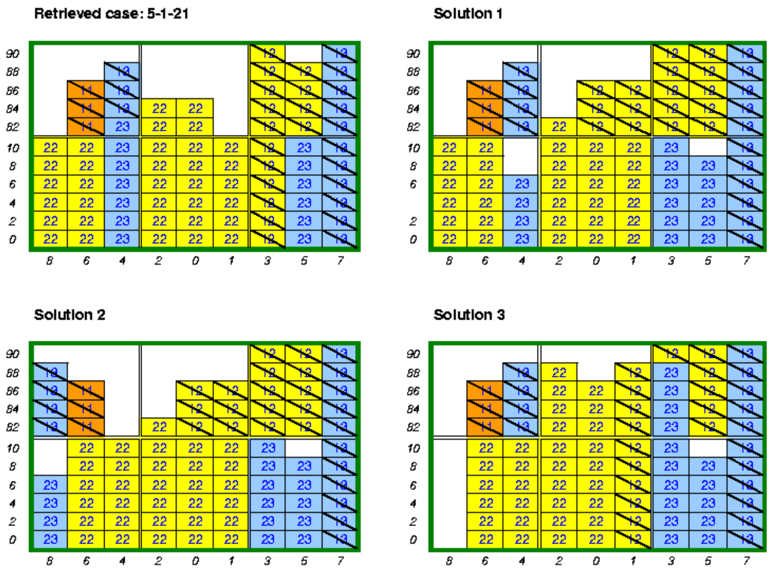


Figure 11. Possible solutions.

After completing the planning process, the stowage plan is commented and stored into the casebase. The casebase is where the knowledge of the stowage planning is stored. The more cases are stored in the casebase, the better the method assist the planner; the efforts for modifying the plan decrease, see Figure 11.

5. PERFORMANCE ISSUES

5.1. Consistency

For the same input, the system will produce exactly the same output. And for a slightly different input, the system will propose a slightly different output as well.

5.2. Robustness

This approach assists the human planner in a natural way. It enhances the remembering capability of a human, by storing and retrieving cases accordingly whenever required. Every plan produced in any planning session, real or hypothetical one, recently increases the volume of the casebase, and can contribute immediately to a new planning session. The more planning sessions stored into the casebase, the more capable the system is to guide the planner to find construct the stowage plan [9]. The CASESTOW is a *learning system* which assists the user to avoid repeating the same mistake, e.g. using a plan concept which might lead to a poor stowage plan.

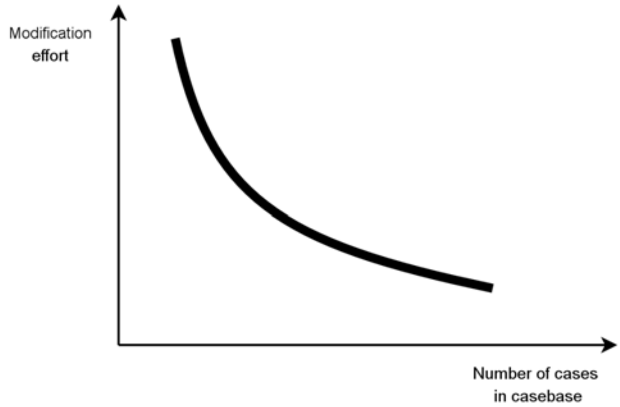


Figure11. Modification effort versus number of cases in the casebase

5.3. Scalability

The system can be applied to any sizes of vessels and for any routes with a minimum effort, i.e. by adapting the similarity metrics accordingly. In contrast to expert system and mathematical modeling approaches, no modification of objective functions or constraints or rules are to be applied.

6. CONCLUSIONS

The case-based stowage planning system, CASESTOW, enables semi-automating the stowage planning process, by retrieving and modifying a past similar stowage plan. The system assists the planner through his natural stowage planning process, and it respects his subjective preferences. Existing stowage planning modules can seamlessly be integrated into the CASESTOW architecture.

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REFERENCE

[1] Agnar Aamodt and Eric Plaza. Case-Based Reasoning: Foundational issues, Methodological Variations and System approaches. *AI Communications*, 7(1):39-54.

[2] Daniela Ambrosino, Anna Sciomachen and Elena Tanfani. Stowing a containership: The Master Bayplan Problem. *Transportation Research Part A*, February 2004.

[3] R. Bergmann, H. Munoz-Avilla, M. Veloso and E. Melis. Case-Based Reasoning Applied to Planning. In M. Lenz, B. Bartsch-Spörl, H.-D. Burkhard and S. Weiss, editors, *Case-Based Reasoning Technology – From Foundations to Applications*. Springer Verlag, 1998.

[4] Yuval Davidor and Moshav Avihail. Method for Determining a Stowage Plan, 15 1998. US Patent number 6809489.

[5] Peter Horstkorte. Stauplanung an Bord von Containerschiffen – eine Problemanalyse. Technical Report (unpublished) , Fachgebiet Seeverkehr, Institut Schiffs- und Meerestechnik, Technische Universität Berlin, Dezember 2000.

[6] Sabine Kujath. *Entwicklung eines Objektorientierten Systems zur Stauplanung*. Master's Thesis, Arbeitsgruppe Diskrete Mathematik, Fachbereich Mathematik, Technische Universität Berlin, 1996.

[7] William Mark. *Machine Learning Methods for Planning*, Chapter: Adapting Plan Architectures, pages 435-465. Morgan-Kauffmann, 1993.

[8] William Mark, Evangelos Simoudis and David Hinkle. In David B. Leake, editor, *Case-Base Reasoning: Experiences, Lessons & Future Directions*, Chapter: Case-Based Reasoning: Expectations and Results, pages 269-294, AAAI Press/ MIT Press, 1996.

[9] Setyo Nugroho. Case representation of a round voyage in a case-based stowage planning system. Slide presentation at Technische Universität Hamburg-Harburg, 11 June 2003.

[10] Rainer Schott. *Stauplanung für Containerschiffe*. Verkehrswissenschaftlichen Studien aus dem Institut für Verkehrwirtschaft der Universität Hamburg. Vandenhoeck & Ruprecht, Göttingen, 1989.

[11] Ian Watson. *Applying Case-Based Reasoning: Techniques for Enterprise Systems*. Morgan-Kauffmann, 1997.

[12] I.D. Wilson, P.A. Roach and J.A.Ware. Container Stowage Pre-planning: Using Search to Generate Solutions - A Case Study. *Knowledge-Based Systems*, (14):137-145, 2001.